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State of Florida
Conservation Plan for Gulf Sturgeon
(*Acipenser oxyrinchus desotoi*)

Anne Wakeford

Florida Fish and Wildlife
Conservation Commission

FMRI Technical Report TR-8 2001

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Cover Photographs

Background: Sturgeon in pickup truck, Blountstown, Florida, 1954 (*Sandy Walko*). *Clockwise from upper left:* University of Florida sturgeon aquaculture project; USFWS sturgeon recovery poster; Ann Wakeford, Choctawhatchee River (*USFWS, Frank Parauka*); sturgeon roe, University of Florida sturgeon aquaculture project; gravid sturgeon, Suwannee River (*University of Florida, Doug Colle*); ultrasonic receiver for sonic tagging (*FWC FMRI*); surgical insertion of sonic tag (*FWC FMRI, Harry Grier*); cross-section of sturgeon pectoral fin ray, used to calculate age (*USFWS*); sturgeon on scales (*USFWS*); sturgeon sampling (*USFWS, Panama City, Florida*).

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State of Florida Conservation Plan for Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

Executive Summary

All modern sturgeon species spawn in fresh water, and some species spend their entire lives there. A number of sturgeon species, however, spend their adulthood in oceanic environments, and still others spend it in brackish water (McEnroe and Cech, 1987). Using this life-history information, Doroshov (1985) divided the extant sturgeon species into three categories: anadromous, semi-anadromous, and landlocked.

Gulf sturgeon are anadromous. They spend the cooler months (October or November through March or April) in estuarine or marine habitats, where they feed on benthic organisms such as isopods, amphipods, lancets, molluscs, crabs, grass shrimp, and marine worms (Mason and Clugston, 1993). In the spring, gulf sturgeon return to their natal river, where the sexually mature sturgeon spawn, and the population spends the next 6–8 months there (Odenkirk, 1989; Foster, 1993; Clugston *et al.*, 1995; Fox *et al.*, 2000).

Gulf sturgeon occur in most major tributaries of the northeastern Gulf of Mexico from the Mississippi River east to Florida's Suwannee River and in the central and eastern gulf waters as far south as Charlotte Harbor (Wooley and Crateau, 1985). In Florida, gulf sturgeon are still found in the Escambia, Yellow, Blackwater, Choctawhatchee, Apalachicola, Ochlockonee, and Suwannee rivers (Reynolds, 1993).

Gulf sturgeon require specific ecosystem conditions to survive. In their riverine habitat, sturgeon require waters that have large areas of diverse habitat; natural variations in flow, velocity, temperature, and turbidity; free-flowing sections to provide suitable spawning sites; and uninhibited access to upriver spawning sites (Pittman, 1992; Beamesderfer, 1993; United States Fish and Wildlife Service [USFWS] and Gulf States Marine Fisheries Commission [GSMFC], 1995). Sturgeon movement, migration, and survival are threatened by river impediments such as barriers to (*e.g.,* dams) and disruptions of (*e.g.,* dam and channel maintenance procedures) spawning sites. The broad habitat needs of sturgeon suggest that only large-scale, ecosystem-wide programs to improve and protect habitat can further the recovery of sturgeon populations (Beamesderfer and Farr, 1997).

The rivers and estuary-bay systems within the present and historical ranges of gulf sturgeon were evaluated to determine the extent of suitable habitat for sturgeon in all life-history stages and to determine the number of resident gulf sturgeon populations present. These systems include the bays and rivers associated with Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay, Apalachicola Bay, Suwannee Sound, and Tampa Bay.

According to the Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995), before recovery measures for gulf sturgeon can be implemented and monitored, the essential habitat requirements of sturgeon must be determined; sturgeon populations and habitats must be protected; and researchers, managers, and policy-makers must share pertinent information.

To identify the ecosystems essential to gulf sturgeon, assess sturgeon population status, and investigate sturgeon life-history requirements, several studies must first be conducted. Essential habitats for each sturgeon life-history stage in each river basin and contiguous estuarine and neritic waters need to be identified. Life-history studies on the requirements of little-known or inadequately sampled gulf sturgeon life stages need to be conducted. Gulf sturgeon populations need to be surveyed, monitored, and modeled. Experimental culture of gulf sturgeon needs to continue, and genetic characteristics of wild and hatchery-reared gulf sturgeon need to be identified.

In order to protect individual sturgeon and sturgeon populations, the unauthorized take of sturgeon (*e.g.,* by poachers or as bycatch) should be reduced or eliminated. Also, biologists need to conduct studies to identify water-quantity and water-quality problems, such as harmful chemical contaminants, that could impede gulf sturgeon recovery. Managers need to develop a regulatory and/or incentive framework to ensure that essential sturgeon habitats, stream flow, and groundwater inflows are protected. In addition, essential habitats must be restored and enhanced for and made more accessible to gulf sturgeon populations. The genetic integrity and diversity of wild and

hatchery-reared gulf sturgeon stocks must also be maintained.

Scientists, managers, and policy-makers from all gulf states need to share information about gulf sturgeon conservation and recovery activities, as well as work together in implementing and monitoring gulf sturgeon recovery programs.

These recommendations for sturgeon recovery involve three types of actions: immediate, short-term, and long-term. Actions needed immediately include identifying relict water-control structures, low-head dams, and other impediments to sturgeon migration. Short-term actions needed include conducting scientific studies and examining more closely both existing and potential problems in Florida gulf-coast rivers and estuaries. Long-term conservation and management actions needed to eliminate threats to sturgeon include improving riverine and estuarine marine habitat, periodic monitoring of these habitats, and ultimately restoring sturgeon as established, self-sustaining populations.

Management objectives, recommendations, priorities, and strategies for the recovery of gulf sturgeon populations must be carefully planned to ensure that systemwide habitat needs of sturgeon are met. Stock enhancement may aid in the recovery of some populations. The conservation plan detailed in this document will be used to aid recovery of gulf sturgeon populations throughout the state of Florida and could be a model for other gulf states to use.

State of Florida
Conservation Plan for Gulf Sturgeon
(*Acipenser oxyrinchus desotoi*)

Introduction

Description of Gulf Sturgeon

BIOLOGY

The species *Acipenser oxyrinchus* (Atlantic sturgeon) consists of two geographically disjunct subspecies: *Acipenser oxyrinchus desotoi* (gulf sturgeon) and *Acipenser oxyrinchus oxyrinchus* (Atlantic sturgeon). The gulf sturgeon differs from the Atlantic sturgeon in the relative head length and pectoral fin lengths, the shape of the dorsal scutes, and the length and the position of the spleen (Vladykov, 1955; Vladykov and Greeley, 1963). Wooley (1985) reexamined these differences and determined that the relative spleen length to fork length was the only statistically reliable characteristic that distinguished the subspecies. Ong *et al.* (1996), using direct sequence analysis of the mitochondrial DNA control region, provided genetic evidence that Atlantic and gulf sturgeon are indeed separate subspecies. The gulf sturgeon's body is subcylindrical and is embedded with cartilaginous plates (scutes), its snout is extended and protruding, its mouth is ventral and has four chin barbels, and the upper lobe of its tail is longer than the lower lobe (Vladykov, 1955; Vladykov and Greeley, 1963). Gulf sturgeon are long-lived, reaching ages of at least 42 years (Huff, 1975). Female sturgeon attain sexual maturity between the ages of 8 and 17 years, and males reach sexual maturity between ages 7 and 12 years (Huff, 1975).

To restore and manage any sturgeon species, resource managers must know the basic requirements of that species in all of its life history stages (Clugston *et al.*, 1995). Table 1 summarizes our current understanding of Gulf sturgeon habitat requirements (USACOE [U.S. Army Corps of Engineers], 1999a).

LIFE HISTORY

Gulf sturgeon are anadromous, and their migration patterns depend on the sex and maturity of the fish and on water temperature. Both adult and subadult sturgeon migrate yearly into saline waters and spend the cooler months (October or November through March or April) in estuarine or marine habitats (Carr, 1983; Foster, 1993). This saline environment provides a rich diversity of benthic food organisms, such as isopods, amphipods, lancets, molluscs, crabs, grass shrimp, and marine worms (Mason and Clugston, 1993). In the spring, gulf sturgeon return to their natal river, where sexually mature sturgeon spawn, and the population spends until October or November (6–8 months) in freshwater rivers (Odenkirk, 1989; Foster, 1993; Clugston *et al.*, 1995; Fox *et al.*, 2000).

Sulak and Clugston (1999) suggested that sturgeon spawning activity in the Suwannee River is related to the lunar phase of the moon and that spawning begins 4–7 days after the new moon, but only after the water temperature has risen to 17°C. Fox *et al.* (2000), in their studies of gulf sturgeon in Choctawhatchee Bay, found that male sturgeon enter the river earlier than females do and move greater distances upstream, searching either for females, potential spawning sites, or both. Males were also found to remain at spawning sites longer than females do. Many researchers have postulated that male gulf sturgeon may spawn annually. In contrast, researchers believe that female sturgeon may require more than one year between spawns.

During their early-life-history stages, sturgeon require bedrock and clean gravel or cobble substrate for eggs to adhere to and for shelter for developing larvae (Sulak and Clugston, 1998). Young-of-the-year (YOY) appear to disperse widely, using extensive portions of the river as nursery habitat. They are typically found on sandbars and sand shoals over rippled bottom and in shallow, relatively open, unstructured areas. This dispersion may be an adaptation to maximize scarce food resources (Randall and Sulak, 1999). Subadult sturgeon, which weigh more than 5 kg, and adult sturgeon in the freshwater middle reaches of the river fast from spring through fall—apparently, they store sufficient nutrient reserves while in the estuary. Mason and Clugston (1993) suggested that water temperature could influence sturgeon feeding behavior in the Suwannee River and that the high water temperatures in the summer may not be conducive to sturgeon feeding. Alternatively, the benthic organisms usually found in upriver areas may not be preferred, may be too small, or in some way may not meet the nutritional needs of the large subadult and adult sturgeon (Clugston *et al.*, 1995).

Table 1. *General habitat preferences of gulf sturgeon.*

Life Stage or Event	Where	When	Bottom Type	Comment or Behavior
All ages except young-of-the-year	Lower, middle, and upper reaches of the main part of the river	Spring–fall	Sand over bedrock or exposed rock w/complex bathymetry, deep areas of river, bends, and holes	Not reproductive, holding and fasting behavior throughout the summer
Spawning adults	Upper reaches	March–April	Limestone bedrock w/covering of gravel and small cobble; cut limestone banks	Water temperatures 17°–19°C. Required pH, DO, and hardness parameters for spawning success could be narrow
Eggs and larvae	Upper reaches	March–April	Same as for spawning adults	Sinking, adhesive eggs attach to hard substrate, larvae are sheltered in rubble or cobble and eddies created by uneven bottom
Juveniles 1–6 years	Close proximity to river mouth, nearshore, or within the estuary	Winter	Unvegetated, sand, and vegetated bottoms near shore preferred	Very active feeding and limited migration in saline areas
Large juveniles and adults >6 years	Gulf of Mexico (both near and off-shore of bays and estuaries)	Winter	Vegetated and unvegetated bottoms	Very active feeding and more extensive longshore migration
All ages entering or moving up rivers in spring staging	Lower, tidally influenced reaches	Early March	Sand over bedrock, uneven bottom, deep areas near bends, holes	"Staging" is behavior to physiologically adjust for change in salinity
All ages moving downstream or leaving river in fall staging		October–November		Bottom type may be less important than access to variable salinity during transitioning from marine to freshwater conditions

POPULATION SIZE

According to Wooley and Crateau (1985), gulf sturgeon occur in most major gulf coast river systems from the Mississippi River east to the Suwannee River and in adjacent marine waters off the central and eastern Gulf of Mexico as far south as Charlotte Harbor. Comparing historical information with current data indicates that both the geographical range of populations and the number of individuals within a single gulf sturgeon population have been reduced (Barkuloo, 1988). In Florida, gulf sturgeon are still found in the Escambia, Yellow, Choctawhatchee, Apalachicola, Ochlockonee, and Suwannee rivers (Reynolds, 1993). Population estimates have been conducted for gulf sturgeon in the Suwannee, Apalachicola, and Choctawhatchee rivers. However, the status of gulf sturgeon populations has not been determined for populations in other Florida gulf coast rivers.

SUWANNEE RIVER

Of the coastal rivers of the Gulf of Mexico, the Suwannee River supports the most viable gulf sturgeon population (Huff, 1975; Gilbert, 1992). According to United States Fish and Wildlife Service (USFWS) and Gulf States Marine Fisheries Commission (GSMFC) (USFWS and GSMFC, 1995), the Suwannee River supports a gulf sturgeon population estimated to be 2,250–3,300 fish. The mean population size from 1987 to 1996 was estimated to be 3,152 individuals (Chapman *et al.,* 1997). Based on mark-recapture studies from 1986 to 1998, Sulak and Clugston (1999) estimated the Suwannee River population to be 7,650 individuals (fish greater than 61 cm in total length and older than age two). M. Allen, University of Florida, Gainesville, is developing a population model for gulf sturgeon in the Suwannee River (Appendices B, C).

APALACHICOLA RIVER

Gulf sturgeon in the Apalachicola River have been studied since 1979, and estimates of the size of the sturgeon population below the Jim Woodruff Lock and Dam (JWLD) have been made periodically since 1981 (G. Carmody, USFWS, personal communication). From 1981 to 1993, 350 gulf sturgeon were tagged and released (USFWS and GSMFC, 1995). In 1983, Wooley and Crateau (1985) estimated the mean number of gulf sturgeon in the Apalachicola River population to be 282 individuals. Population estimates from 1983 to 1988 by USFWS biologists from Panama City ranged from 60 to 285 sturgeon (USFWS and GSMFC, 1995). According to Zehfuss *et al.* (1999), a population of approximately 100 gulf sturgeon greater than 45 cm in total length occupies the Apalachicola River below the JWLD. However, in their studies, Zehfuss *et al.* (1999) reported that because radio-tagged gulf sturgeon frequently moved in and out of the sample area, the estimated population size could be less than the true population size. In 1998 and 1999, scientists conducted mark-recapture studies below the JWLD and estimated the summer populations of subadult and adult gulf sturgeon to be 270 and 321 individuals, respectively (USFWS, 1998, 1999). If the sturgeon population of the Brothers River, a tributary of the Apalachicola River, is added to the Apalachicola population, the population size of resident gulf sturgeon in the Apalachicola system below the JWLD could be as many as 500 fish. Important habitats for gulf sturgeon appear to be deep, rocky holes in mid-river; in the tailrace of the Jim Woodruff Dam; and in the deep, still waters of oxbow lakes (Edmiston and Tuck, 1987, cited in FDEP 1998b).

CHOCTAWHATCHEE RIVER

In the summer, gulf sturgeon in the Choctawhatchee River occupy one of several discrete areas, each approximately 2–3 km in length, in the lower to middle river (Zehfuss *et al.,* 1997). This pattern of movement has been documented for other sturgeon species and subspecies: Atlantic (*Acipenser oxyrinchus oxyrinchus,* Moser and Ross, 1995), shovelnose (*Scaphirhynchus platorynchus,* Hurley *et al.,* 1987), and shortnose (*Acipenser brevirostrum,* Dadswell, 1979).

According to Zehfuss *et al.* (1997), the four areas most frequently used by sturgeon in the Choctawhatchee River include wide, straight stretches with moderate current velocities; narrow sections of the river characterized by sharp curves; exposed limestone outcroppings; and areas below spring outlets. However, Zehfuss *et al.* (1997) also suggested that depth and velocity might not be important factors to sturgeon selecting habitat in the Choctawhatchee River because the fish also occupy stretches closer to the bank of the river that are shallow (3–4 m) and do not have deep holes. Bank overhangs may also provide hydraulics and protection similar to those provided by deep holes.

A total of 444 subadult and adult gulf sturgeon were collected and tagged in the Choctawhatchee River in October and November 1999. Based on the preliminary analysis of the 1999 recapture data, the population of subadult and adult gulf sturgeon in the Choctawhatchee River may be approximately 3,000 fish (USFWS, 1999). During a 5-week sampling period in the fall of 2000, 196 sturgeon were tagged on the Choctawhatchee River, and the population was estimated to be 1,815 sturgeon (F. Parauka, USFWS, Panama City, personal communication).

Fishing and Aquaculture

FISHING

For hundreds of years, all sturgeon species have been harvested without restriction and captured in nets as bycatch. Historically, sturgeon have been the most commercially valuable freshwater fish in Florida. Gulf sturgeon supported both commercial and recreational fisheries throughout most of their range from the Mississippi River east to Tampa Bay (U.S. Commission of Fish and Fisheries, 1902, cited in Wooley and Crateau, 1985; Burgess, 1963; Lee *et al.,* 1980). Large-scale exploitation of gulf sturgeon began around 1860, when it was learned that smoked sturgeon could be substituted for smoked halibut and that sturgeon eggs could be made into high-quality caviar (Smith, 1990). Commercial landings statistics compiled by Huff (1975) and Barkuloo (1988) show that the number of gulf sturgeon has declined precipitously in Florida since the turn of the century. Directed fisheries for gulf sturgeon occurred only along the Florida and Alabama coasts, but no information is available to calculate catch per unit effort (Smith and Clugston, 1997). Sturgeon have been harvested with gillnets, pound nets, otter trawls, harpoons, trammel nets, weirs, stake row nets, and seines (Huff 1975; Smith 1985; Van Den Avyle, 1984; Smith and Clugston, 1997). Lack of regulations for harvesting sturgeon prior to the middle 1980s and lack of rules for the incidental harvest of sturgeon as bycatch in other fisheries helped bring about the declines in gulf sturgeon populations.

Bycatch of sturgeon has been reported in many different fisheries, such as riverine and estuarine gillnet and estuarine and marine trawl fisheries both in nearshore areas and in the Exclusive Economic Zone (EEZ). Roithmayr (1965, cited in USFWS and GSMFC, 1995) reported the incidental catch of gulf sturgeon in the industrial bottomfish (pet food) fishery in the north-central Gulf of Mexico from 1959 to 1963. Incidental captures of gulf sturgeon by commercial shrimpers and gillnet fishers in Apalachicola Bay were reported by Swift *et al.* (1977) and Wooley and Crateau (1985). Gulf sturgeon are still captured as bycatch in shrimp trawl fisheries in Choctawhatchee and Apalachicola bays (D. Fox, North Carolina State University [NCSU], personal communication).

Florida statutes prohibit shrimp trawling in four estuaries, which may help protect gulf sturgeon populations. Florida Administrative Code (F.A.C.) 68B-31.017 closes 191,300 hectares of the Big Bend area to shrimp trawling year round. F.A.C. 68B-31.018 closes 10,522 hectares of Apalachicola Bay and St. Vincent Sound, 526 hectares of St. George Sound, and 20,072 hectares of Ochlockonee Bay to shrimp trawling all year and calls for seasonal closures of 2,630 hectares in Apalachicola Bay and St. Vincent Sound from March 1 to May 31 and 3,480 hectares in St. George Sound from September 15 to December 31.

AQUACULTURE

Hatcheries function principally to increase survivorship of sturgeon in the early year-classes, typically eggs and young-of-the-year (YOY) (Piper *et al.,* 1982). Harvest regulations control the number of sturgeon harvested, the age or size of the sturgeon harvested, or the time of year that sturgeon may be taken from a population. Harvest regulations can also attempt to reduce poaching, a serious problem for sturgeon (Kynard, 1997). Habitat improvements that increase survivorship of YOY will make strong contributions to population growth. Conversely, habitat improvements that increase fecundity or survivorship of a specific year-class (such as increased feeding opportunities for adult sturgeon) will bring about less of an increase in population growth (Beamesderfer and Farr, 1997).

The incidental or accidental introduction of non-indigenous species into areas where wild populations of sturgeon exist may pose a threat to the biodiversity of large ecosystems. Effluent water from aquaculture facilities and sturgeon and other fish that accidentally escape from such facilities to the wild can introduce, transmit, and spread disease and parasites to native sturgeon populations (Haywood, 1998). Information gathered at The Sturgeon Culture Risk Assessment Workshop, held April 6–7, 2000 (Metcalf and Zajicek, 2001) was used to formulate Best Management Practices (BMPs) for sturgeon aquaculture in Florida (Appendix B). According to M. Gross (University of Toronto, personal communication), three major factors—hatcheries, harvest, and habitat—affect sturgeon populations (Table 2).

Protections, Listings, and Recovery Plans

The paragraphs that follow describe, in chronological order, the various actions that have been taken to protect gulf sturgeon.

FLORIDA SPECIES OF SPECIAL CONCERN, 1979

The Florida Administrative Code 68A-27.005, Florida Constitution Article IV, Section 9, August 1, 1979, designated Atlantic sturgeon (of which the gulf sturgeon is a subspecies) as a species of special concern. The gulf sturgeon was included in the Atlantic sturgeon designation because the gulf sturgeon, like Atlantic sturgeon, is also highly vulnerable to habitat modification, environmental alteration, human activities, and human exploitation. If appropriate protective or management techniques are not initiated or maintained, gulf sturgeon may, one day, be designated as a threatened species.

MORATORIUM IN FLORIDA, 1984

Florida has prohibited commercial fishing for gulf sturgeon since November 25, 1984 (Florida Marine Fisheries Commission, Rule 46-15.01-02, incorporated in F.A.C. 68B-15.001)."No person, firm, or corporation shall take, disturb, mutilate, molest, harass, or destroy any sturgeon of the species *Acipenser oxyrinchus desotoi,* unless it is by accident. Any Gulf sturgeon accidentally caught shall be returned to the water immediately. In accordance with Section 370.10 (2) Florida Statutes (F.S.), the Florida Fish and Wildlife Conservation Commission (FWC) may issue permits to collect and possess sturgeon for experimental, scientific, and/or educational purposes."

***Table 2**. Positive and negative effects of hatcheries, harvest, and habitat on sturgeon populations and the change required to mitigate those effects.*

Effects	Hatcheries	Harvest	Habitat Protection or Improvement
Positive	• Increase survivorship in early year-classes (i.e., eggs and YOY) • Hatcheries affect the most sensitive age classes • Socially popular with many groups of people	• Effects on native species are often underestimated (impact can often be cumulative and/or biased over time) • Inexpensive • Quick fix to problem	• All ages of fish can benefit • Aquatic community can benefit from protection • Socially acceptable to all groups of people
Negative	• <100% of fish species affected • Trade-off of benefiting juveniles at expense of adults • Ecological, evolutionary, and genetic concerns • Treats symptom, not cause of problem	• Adult and subadult life-stage oriented • Older, sexually mature fish affected • Socially unpopular	• Expensive to implement measures to protect and improve habitat • Slow to observe results of habitat protection
Change required	• Correct way to quantify • Appropriate age selection of individuals to be released • Quantity of individuals released vs. quality of individuals released • Mitigate ecological/ evolutionary concerns • Education of biologists and general public	• From targeted older individuals • From target eggs • Education needed for fishers and biologists	• Need to focus on habitat needs of YOY • Need to spread benefit of habitat restoration across all life-history stages • Need to educate biologists and managers

REPORT ON THE CONSERVATION OF THE GULF OF MEXICO STURGEON, 1988

The 1988 USFWS Report on the Conservation Status of Gulf Sturgeon initiated discussions about the classification of, status of, essential habitats for, geographic distribution of, life history of, threats to the survival of, and conservation recovery recommendations for gulf sturgeon (Barkuloo, 1988).

U.S. ENDANGERED SPECIES ACT, 1991, SECTION 4(D) RULE

The gulf sturgeon was listed as a threatened species on October 30, 1991, pursuant to the Endangered Species Act (ESA) of 1973. The Secretary of Commerce has the discretion, under Section 4(D) of the act, to issue special regulations that are necessary and advisable for the conservation of a threatened species. In order to avoid unnecessary duplication of permitting requirements, the USFWS and the National Marine Fisheries Service (NMFS) promulgated a special rule. This rule allows the take of gulf sturgeon, in accordance with applicable state laws, for educational and scientific purposes; the enhancement, propagation, or survival of the species; zoological exhibition; or other conservation purposes consistent with the ESA. Taking for purposes other than those described, including taking incidental to carrying out otherwise lawful activities, is prohibited except when permitted under the Code of Federal Register (C.F.R.) 17.32. The ESA, 50 C.F.R., Part 17, identifies the need for the protection of and recovery provisions for gulf sturgeon. This special rule was created to allow conservation and recovery activities for the gulf sturgeon to be carried out without a federal permit, provided those activities are in compliance with applicable state laws. Pursuant to Section 4(f)(1) of the ESA, the NMFS and the USFWS are required to develop and implement recovery plans"for the conservation and survival of endangered and threatened species." Conservation is defined as the use of all methods and procedures needed to bring the species to the point at which listing under the ESA is no longer necessary (Federal Register, 1991). The purpose of the listing is to prevent further declines of gulf sturgeon populations that may become endangered within the foreseeable future.

FLORIDA NET BAN, 1994

The Florida net ban referendum, passed in November 1994, banned entangling nets (gillnets and trammel nets) in nearshore and inshore Florida waters. Other types of nets, such as seines, cast nets, and trawls, can be used for fishing if the total area of the net mesh is less than 46 m^2 (Florida Department of Labor and Employment Security, 1995). The elimination of entangling nets was intended to reduce the commercial fishing pressure on the targeted species as well as on those species caught incidentally as bycatch.

GULF STURGEON RECOVERY/ MANAGEMENT PLAN, 1995

The Gulf Sturgeon Recovery/Management Plan was prepared by the gulf sturgeon recovery/management task team for the Southeast Region to aid in the recovery of gulf sturgeon populations (USFWS and GSMFC, 1995). The short-term recovery objective of the plan is to prevent further decline of existing populations of gulf sturgeon within the range of the species. Long-term objectives for gulf sturgeon recovery include establishing the minimum number of sturgeon necessary in each river system to maintain the population in that river system. This minimum number would give managers a benchmark for delisting, by river system, recovered populations of gulf sturgeon. To determine this minimum number, we must compile data about gulf sturgeon life-history characteristics and analyze the factors required to develop self-sustaining sturgeon populations in which recruitment is equal to or greater than mortality. A further, longer-term objective is to establish sturgeon stocks that could sustain, following delisting, directed fishing pressure.

CHAPTER 370.31 F.S., 1996

In 1996, the Florida legislature enacted F.S. 370.31 to promote the commercial production of and aid in the stock enhancement of sturgeon in Florida. This statute called for the creation of the Florida Sturgeon Production Working Group (FSPWG) to establish a state sturgeon aquaculture and conservation program. The legislature, recognizing the emerging interest in commercial sturgeon aquaculture, funded the Florida Sturgeon Program in 1999 to balance aquaculture and conservation interests in Florida. By creating the program, the legislature has provided assurance that aquaculture will benefit native sturgeon conservation rather than harm it.

APPENDIX II OF THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES), 1998

To ensure that commercial demand does not threaten their survival in the wild, many wildlife species are protected by CITES, a treaty that regulates trade in the species listed in it (including hybrid and captive-bred sturgeon) through a permits system (USFWS, International Affairs, 1998). Under CITES, a species is listed in its appendices as needing one of three levels of protection; permit requirements, determined with the goal of sustaining the species at acceptable levels, are different for each level of protection. To curtail trade in illegally obtained caviar and to ensure that stocks of wild sturgeon—particularly Caspian Sea species—are managed and sustained, all sturgeon species have now been listed in Appendix II of CITES; gulf sturgeon were listed in April 1, 1998. Appendix II includes species that may be threatened with extinction if their trade is not regulated and monitored. Specimens of species listed in Appendix II require an export permit, which may be issued for any purpose as long as the specimens were legally acquired and export is not detrimental to the species. Specimens exported to establish a sturgeon breeding program or to be used in spawning offspring that will be sold in another country are considered to be exported for commercial purposes (USFWS, International Affairs, 1998). The listing of sturgeon in CITES provides managers with a mechanism for regulating the import and export of sturgeon and their products, thereby curtailing the illegal caviar trade and the harm it causes to the wild populations. The USFWS, Division of Law Enforcement, is responsible for the enforcement of CITES and is the permit and enforcement authority responsible for regulating the importation of sturgeon from foreign countries.

Habitat Requirements

The broad habitat needs of all sturgeon species suggest that only large-scale, ecosystem-wide programs to improve and protect habitat can further the recovery of sturgeon populations (Beamesderfer and Farr, 1997). Because sturgeon require a wide range of environmental conditions in order to survive, their habitat must be defined in terms of ecosystems. The most important ecosystem requirements for sturgeon are large areas of diverse habitat that have natural variations in water flow, velocity, temperature, and turbidity (Carlson *et al.,* 1985; Crance, 1986; Mosindy, 1987; Payne, 1987; Curtis, 1990; Taub, 1990; Lane, 1991; Pittman, 1992; Beamesderfer, 1993; USFWS, 1993; USFWS and GSMFC, 1995). Sturgeon, like many fish, are most sensitive to environmental disturbances during their early-life-history stages (Chapman and Carr, 1995).

Water-Quality Requirements for Sturgeon

FLOW–RATE REQUIREMENTS

Several researchers have suggested that strong, persistent water flow is necessary for sturgeon to spawn (Votinov and Kasyonov, 1979; Parsley *et al.,* 1993; Auer, 1996a; Kieffer and Kynard, 1996). High levels of water flow could also be correlated with sturgeon migratory activity. Thus, river flow may serve as an environmental cue that governs both sturgeon migration and spawning (Chapman and Carr, 1995). If the flow rate is too high, however, sturgeon in several life-history stages can be adversely affected. Data describing the sturgeon's swimming ability in the Suwannee River strongly indicate that they cannot continually swim against prevailing currents of greater than 1-2 meters per second (K. Sulak, USGS, personal communication). Also, if the flow is too strong, eggs might not be able to settle on and adhere to suitable substrate. Section 373.042 F.S. directs Florida's water management districts to establish "minimum flows" and "minimum levels" for watercourses. The statute defines minimum flows as "the limits at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Increases in the human population and in the development of lands surrounding gulf coast rivers has resulted in altered ground-and-surface-water flows. These altered flows are not suitable for gulf sturgeon and have further limited their habitat.

DISSOLVED OXYGEN

Many sturgeon species are oxyphilic, requiring high levels of oxygen. Laboratory hypoxia tests on shortnose sturgeon (*Acipenser brevirostrum*) indicate that fish 104–310 days old were able to tolerate low oxygen levels for only short periods (Jenkins *et al.,* 1993). In further laboratory experiments, young shortnose sturgeon (less than 77 days old) died at oxygen levels of 3.0 mg/l, and all age groups of these sturgeon died at oxygen levels of 2.0 mg/l (Jenkins *et al.,* 1993). Laboratory research to determine oxygen requirements for gulf sturgeon is currently being conducted by D. Parkyn at the University of Florida, Gainesville (Appendices B, C).

TEMPERATURE/SPRINGS

Change of temperature is one of the most important factors in initiating sturgeon migration (Wooley and Crateau, 1985; Chapman and Carr, 1995; Foster and Clugston, 1997). Adult and large juvenile gulf sturgeon swim upriver from the Gulf of Mexico in the spring when water temperatures are 15°–20°C (Chapman and Carr, 1995; Sulak and Clugston, 1998; Fox *et al.,* 2000), and sturgeon swim downstream and return to salt water in the fall when surface-water temperatures are 18°–23°C (Foster and Clugston, 1997).

In the Suwannee River, summer settlement areas for sturgeon are located just downstream from large springs, although the sturgeon do not actually enter the springs or the thermal plumes coming from springs (Foster and Clugston, 1997). Initially, researchers believed that sturgeon did not roam far from springs in the summer, because the cold water provided a thermal refuge. However, Sulak and Clugston (1998, 1999) showed that spring effluent cools the adjacent water in the Suwannee River by only about 0.1°C.

Laboratory experiments show that gulf sturgeon eggs, embryos, and larvae have the highest survival rates when temperatures are between 15°C and 20°C; mortality rates of gulf sturgeon gametes and embryos are highest when temperatures are 25°C and above (Chapman and Carr, 1995).

Factors Required for Successful Sturgeon Spawning

WATER QUALITY

Most of Florida's rivers that flow into the Gulf of Mexico have a high concentration of tannin and are acidic. However, limestone outcroppings that extend into the water along the banks of many of these rivers increase water alkalinity and therefore buffer the water's acidity. In addition, the aquifer springs and seeps located in many of Florida's west coast rivers help produce more alkaline water conditions. Limestone rocks along the banks of the rivers provide an important source of calcium, and high levels of calcium result in high levels of conductivity and water hardness.

In their studies on Suwannee River gulf sturgeon, Sulak and Clugston (1999) demonstrated that spawning gulf sturgeon require a neutral to slightly alkaline pH, a conductivity range of 40–100 microsiemens, and a corresponding ionic range of 6–18 mg/l of calcium ions. Adult sturgeon may not spawn if one or more of these parameters are significantly outside these ranges. In the Suwannee River, gulf sturgeon spawn annually during spring high water when conductivity and ionic strength are diminished by surface runoff from spring rains. Early-summer conductivity levels surpass 200 microsiemens (Sulak and Clugston, 1999), which is unsuitable for spawning.

SPAWNING SUBSTRATE

Sturgeon also require hard-bottom substrates such as rocks or a cobble-gravel mixture on which to lay their eggs (Doroshov, 1985). The substrate matrix of exposed bedrock overlain with gravel and small cobble characteristically used by spawning gulf sturgeon has been called a "sturgeon spawning reef" (Sulak and Clugston, 1999). Bedrock and clean gravel substrate also appear to be critical biological requirements for sturgeon in the early-life-history stages because they offer eggs a surface to adhere to and developing larvae shelter (Sulak and Clugston, 1998). At sites where sturgeon eggs are collected along the Suwannee River, the river banks are composed of limestone bluffs and outcroppings, and the river bottom consists of cobble, limestone gravel, and sand. The water depth ranges 1.4–7.9 m, and water temperature ranges 18.3°–22°C (Marchant and Shutters, 1996; Sulak and Clugston, 1999). If sturgeon spawn in areas of soft bottom (mud-sand), the eggs can quickly become encapsulated within a layer of sediment and suffocate (Fox *et al.,* 2000).

Major Impediments to Gulf Sturgeon Recovery in Rivers

Major impediments to the recovery of gulf sturgeon populations in rivers include barriers to and disruptions of spawning sites, dam and channel maintenance, and deterioration of water quality. Gulf sturgeon require access to the upper reaches of major coastal rivers to reproduce.

BLOCKAGE AND DISRUPTION OF SPAWNING SITES

When barriers block access to spawning sites, or when those sites are disrupted, sturgeon lose important habitat. Dams, siltation, pollution, and water degradation have contributed to the demise of many sturgeon populations (Rochard *et al.,* 1990; Bernstein, 1993; Smith and Clugston, 1997). In addition, many rivers emptying into northwestern Florida are impounded (Apalachicola and Ochlockonee), diverted (Pea River branch of the Choctawhatchee), or polluted (Fenholloway), and thus provide limited areas where sturgeon can spawn (Randall and Sulak, 1999). Another problem is that when migratory routes are blocked, more than one species of sturgeon may be forced to use the same habitat for spawning, and hybridization may occur between species (Auer, 1996b). For example, the natural ranges of pallid (*Scaphirhynchus albus*) and shovelnose (*S. platorynchus*) sturgeon overlap. However, locks, dams, and impoundments on the Mississippi River have trapped these species, and where they occur in close proximity, hybrid sturgeon are complicating study of the life histories of pallid and shovelnose sturgeon (Carlson *et al.*, 1985).

By collecting fish for scientific research, biologists could disrupt sturgeon spawning runs and thus impede recovery of some gulf sturgeon populations (M. Moser, NMFS, personal communication). In aquaculture research experiments, sturgeon eggs and sperm are extracted from wild, sexually mature adults for study, and in ecosystem research projects, wild and cultured sturgeon are tagged and tracked to determine migration, movements, and habitat preferences. Both types of research could adversely affect sturgeon migration, movement, and spawning success within a given sturgeon population.

DAMS, SILTATION, AND CHANNEL MAINTENANCE

Habitat degradation and alterations caused by dredging, disposal of debris and dredged material into rivers, and development activities affecting estuarine and riverine mudflats and marshes remain a constant threat to sturgeon populations. Also, siltation and discharge from dams have made rivers shallower, and this loss of habitat could be a cause for the reductions in the numbers of gulf sturgeon in the Apalachicola and Ochlockonee rivers. Dam maintenance, such as minor excavations along the shore, release silt and other fine sediments into rivers, which can degrade critical habitats where sturgeon spawn (Shortnose Sturgeon Recovery Team, 1998; USFWS and NMFS, 1998). Dams also alter river flows and temperatures, both of which need to be at a certain level for sturgeon to successfully migrate and spawn (Auer, 1996a; Shortnose Sturgeon Recovery Team, 1998). Because sturgeon require adequate river flows and 15°–20°C water temperatures for spawning, any dam that alters a river's natural flow pattern, including by increasing or reducing discharges, can be detrimental to sturgeon reproductive success. Gulf sturgeon may be injured or killed if they are entrained in or impinge upon the hydraulic dredges that may be in operation in bays and estuaries from September through March, when gulf sturgeon are usually there (G. Carmody, *in litt.* to S. Rees)[1].

Dredging and filling disturbs benthic fauna, eliminates deep holes, and alters rock substrates; these disruptions can adversely affect gulf sturgeon survival

[1]G. Carmody (*in litt.*). Letter to Susan Rees, Mobile District Corps of Engineers, April 2000. Re: Biological opinion of two mile navigation project (TM Project) (FWS #4-P-99-193) located in Apalachicola Bay, Franklin County, Florida.

(Smith and Clugston, 1997). The U.S. Army Corps of Engineers (USACOE, 1996) found that a dredging operation drastically changes the species diversity, abundance, and age composition of the benthic community that remains after the dredging is completed. Although benthic invertebrates are often able to recolonize a disturbed area within 12–18 months, the new invertebrate fauna may be different and may not be as desirable or as nutritionally valuable to predators as previous food sources were. The 1970 National Estuary Study (as reviewed by Smith and Clugston, 1997) indicated that dredging and filling activities were particularly destructive to fish habitat and reported that 73% of U.S. estuaries have been moderately to severely degraded by these activities. Gulf sturgeon may also be displaced from overwintering feeding habitats by dredge operations (G. Carmody, *in litt.* to S. Rees[1]).

DETERIORATION OF WATER QUALITY

Poor water quality, especially low levels of dissolved oxygen, has degraded shortnose sturgeon (and probably gulf sturgeon) nursery grounds in many southeastern coastal rivers (Collins *et al.,* 2000). Heavy metals and pesticides, such as arsenic, mercury, and DDT, have been shown to accumulate in gulf sturgeon because of their bottom-dwelling habits and have caused reproductive failure, lower survival rates, and physical and physiological problems in gulf sturgeon (Bateman and Brim, 1995). Atlantic sturgeon exposed to polychlorinated biphenyls (PCBs) experience a higher incidence of fin erosion, epidermal lesions, blood anemia, and an impaired immune response than do Atlantic sturgeon that have not been exposed to PCBs (Kennish *et al.,* 1992).

Estuaries and Rivers

Two key needs identified during the development of Florida's Gulf Sturgeon Conservation Plan are to evaluate west coast rivers, estuaries, and watershed basins for the presence of suitable habitat for all sturgeon life-history stages and to determine the number of fish in each gulf sturgeon population. Information gathered in past studies about the habitat characteristics required by gulf sturgeon in rivers and estuaries can then be combined with information gained during these two needed evaluations so that systemwide habitat requirements for gulf sturgeon can be determined.

LAND ACQUISITION PROGRAMS

In 1981, the Florida Legislature established within the Florida Department of Natural Resources (now within the Florida Department of Environmental Protection [FDEP]) the Water Management Lands Trust Fund (WMLTF). The WMLTF, commonly known as the Save Our Rivers (SOR) program, was a nonlapsing fund for the acquisition, management, maintenance, and capital improvement of lands in accordance with Section 373.59 F.S. Monies from the WMLTF are used to acquire lands necessary for water management, water supply, and the conservation and protection of water resources. The WMLTF now consists of the following Florida agencies: FDEP, St. John's Water Management District (WMD), Northwest Florida WMD, Suwannee WMD, Southwest Florida WMD, South Florida WMD, Florida Communities Trust, Florida Department of Agriculture and Consumer Services (FDACS), and Florida Game and Freshwater Fish Commission[2] (GFC; now Florida Fish and Wildlife Conservation Commission [FWC]). Nongovernmental organizations include The Nature Conservancy (TNC), Trust for Public Land, Florida Audubon Society, and 1000 Friends of Florida.

Part of the SOR legislation created a program in which each of Florida's water management districts are required to file a five-year plan of land acquisitions with the legislature and with the Secretary of FDEP (SWFWMD, 2000). In 1990, the Florida Preservation Act, P2000 (Section 259.101 F.S.), continued the SOR program. In late 1999, the Florida Forever Program was created (Section 259.105 F.S.), which extended the land-acquisition program for another ten years and is responsible for acquiring public land for the purpose of protecting habitat. The principal organizations involved in managing resources in Florida include the WMDs, the FWC, and the FDEP. The Florida Forever Program will be funded at $300 million per year, for a total of three billion dollars over its lifetime. For land acquisition through this program, the WMDs receive 35%, the FDEP receives 35%, and the FWC receives 1.5% (FDEP, 2000a). The Conservation and Recreational Lands (CARL) Program is the trust fund established by the Florida Legislature that provides a means of acquiring and managing environmentally sensitive and endangered lands for recreation, water management, and preservation of significant archaeological and historic sites (FDEP, 2000b).

OUTSTANDING FLORIDA WATERS AND STATE AQUATIC PRESERVES

Outstanding Florida Waters (OFW) are designated by the Environmental Regulation Commission (F.S. 430.061 [27]), as being worthy of protection because of their natural attributes. OFWs have exceptional recreational or ecological significance and may not be dredged,

[2]The Florida Game and Freshwater Fish Commission and parts of FDEP, including the Florida Marine Fisheries Commission, FMRI, and the Marine Patrol, were merged in 1999 to become the Florida Fish and Wildlife Conservation Commission (FWC).

Table 3. *A comparison of Florida west coast bays.*

Bay	Area (Size)	Average Depth	Seagrass Coverage	Primary Impacts
Pensacola	140 km^2	2–6 m	5%	sediments, erosion, runoff, pollutants
Choctawhatchee	48 km^2	3–13 m	3%	sediments, development, runoff
St. Andrew	350 km^2	5–8 m	9–10%	sediments, runoff, pollutants
Apalachicola	549 km^2	1–4 m	7%	high turbidity
Suwannee	54 km^2	1–3 m	patchy	pollution
Tampa	1,036 km^2	3 m	8%	sediments, eutrophication, development
Charlotte	699 km^2	3 m	5%	water flow and quality, erosion

filled, logged, or changed in any way, and permits for any alterations are strictly regulated by the FDEP. State Aquatic Preserves are also regulated by FDEP and have been established to preserve state-owned submerged lands in areas that have exceptional biological, aesthetic, and scientific value.

The most important watersheds for gulf sturgeon include the estuaries, bays, and major rivers associated with Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay, Apalachicola Bay, Suwannee Sound, and Tampa Bay. Federal and private organizations, Florida WMDs, the FDEP Division of State Lands, the Acquisition Restoration Council, the Florida Natural Areas Inventory, and other state organizations will use the Florida Conservation Plan for Gulf Sturgeon to determine acquisition projects that will benefit gulf sturgeon.

ESTUARIES

Estuaries are highly productive and contain habitats that serve as nursery grounds and refuges for many fish species. More than 90% of the fish species present in nearshore Florida coastal waters use estuaries during part of their life cycle (Lewis, 1986). Estuarine ecosystems are sensitive to pollution inputs, and many times, habitats are degraded or lost because of the cumulative effects of many small impacts, none of which alone would produce a significant degradation (Lewis, 1986).

Estuarine seagrass beds with mud and sand substrates appear to be important overwintering and feeding habitats for gulf sturgeon (Mason and Clugston, 1993). Benthic invertebrates, gulf sturgeon's primary food, have been a useful indicator for assessing environmental quality in estuaries (Harper *et al.,* 1981, cited in McRae *et al.,* 1998; Engle *et al.,* 1994, cited in McRae *et al.,* 1998; Mason *et al.,* 1994).

The west coast of Florida contains almost 22% of the entire U.S. gulf coast estuarine acreage. More than half of this acreage is unvegetated bottom, and the remainder comprises approximately equal areas

Table 4. *Eutrophic conditions and symptoms (Bricker et al., 1999).*

Estuary	Eutrophic Condition	Symptom Primary Chlorophyll a	Epiphyte	Macroalgae	Secondary Low Oxygen	SAV[1] Loss	Toxic Blooms
Pensacola	moderate	moderate	?	?	moderate	moderate	none
Choctawhatchee	high	moderate	high	low	moderate	moderate	none
St. Andrew	moderate	moderate	low	low	moderate	?	low
Apalachicola	moderate	moderate	none	none	moderate	none	moderate
Suwannee	moderate	moderate	none	moderate	low	none	low
Tampa	high	high improved	none	improved	low	improved	moderate improved
Charlotte	high	high	moderate	none	high	low	none

[1]SAV = submerged aquatic vegetation

Table 5. *Eutrophic conditions and factors influencing the major estuaries of western Florida.*

Estuary	Eutrophic Condition	Overall Human Influence	Susceptibility to Eutrophication	Nitrogen Input
Pensacola Bay	moderate	high	moderate	moderate
Choctawhatchee Bay	high	high	moderate	moderate
St. Andrew Bay	moderate	moderate	moderate	low
Apalachicola Bay	moderate	high	moderate	moderate
Suwannee Sound	moderate	low	moderate	low
Tampa Bay	high	high	moderate	moderate
Charlotte Harbor	high	high	high	low

of submerged vegetation, tidal marshes, and mangrove forests (McNulty *et al.*, 1970, cited in Seaman, 1988; Tables 3–5).

Some of the estuarine systems show signs of eutrophication, such as the loss of submerged aquatic vegetation, increased turbidity associated with high concentrations of chlorophyll a, and low levels of dissolved oxygen; moderate to high levels of toxic algal blooms and epiphyte abundance also often occur in systems with pronounced eutrophication. The principal factors that contribute to the development of moderate to high levels of eutrophication include low tidal energy, low flushing rates and the resultant increase in nutrient inputs, and low levels of dissolved oxygen brought about by warmer water temperatures and longer land-based agricultural growing seasons. Because the dominant land uses along the Florida's northwest coast are agriculture and silviculture, their practices are common management targets. However, wastewater treatment plants, industrial discharges, and atmospheric inputs also contribute to eutrophication. However, the overall conditions in these estuaries are improving because levels of point- and nonpoint-source pollutants have been reduced as a result of better management practices, but nutrient inputs still need to be reduced in areas of moderate to high levels of eutrophication.

Table 6. *A comparison of river classifications.*

River	Wharton	Beck
Escambia	blackwater	large
Yellow	blackwater	sand bottom
Blackwater	blackwater	sand bottom
Choctawhatchee	alluvial	large
Apalachicola	alluvial	large
Ochlockonee	blackwater	sand bottom
Suwannee	blackwater/spring	calcareous
Hillsborough	spring	sand bottom/ calcareous

RIVERS

Rivers that feed these estuaries are also sensitive to pollution and habitat degradation and will be evaluated to determine whether they can support the reestablishment of gulf sturgeon populations (Appendix Figure A1). West coast rivers of Florida can be classified according to schemes proposed by Wharton *et al.* (1982), Berner (1950), and Beck (1965) (all cited in Seaman, 1988).

Wharton *et al.* (1982, cited in Seaman, 1988) differentiated five types of streams: (1) alluvial streams have extensive floodplains, form prominent swamps, and have seasonally elevated discharges from tributaries and rainfall; (2) blackwater streams receive most of their water from rainfall and groundwater seepage and are highly colored by tannic acid; (3) spring-fed streams receive their water from the aquifer; (4) bog and (5) bog-fed streams resemble shallow ravines and receive seepage from adjacent sandy ridges. Several Florida rivers have characteristics of more than one of the above stream types. Berner (1950, cited in Seaman, 1988) divided rivers into three basic groups: stagnant rivers, slow-flowing deep rivers, and large calcareous rivers. Beck (1965, cited in Seaman, 1988) categorized streams based upon a combination of velocity, substrate, vegetation, temperature, oxygen levels, water hardness, and pH, which are basic factors that influence the distributions of benthic invertebrates. Beck's classification differentiated sand-bottomed streams, calcareous streams, larger rivers, swamp and bog streams, and canals of southeastern Florida. Table 6 shows how Wharton (1982, cited in Seaman, 1988) and Beck (1965, cited in Seaman, 1988) classified rivers that currently contain or historically contained gulf sturgeon, and Table 7 gives the physical characteristics of those rivers (from Seaman, 1988).

The following sections describe the topographies and physical characteristics of the Florida gulf coast

Table 7. *Physical characteristics of Florida west coast rivers.*

River	Total Length/ Florida Length(km)[1]	Gradient (m/km)	Drainage (km^2)	Average Flow (m^3/s)
Escambia	148/87	0.72	10,878	180.7
Yellow	148/98	0.57	3,626	33.6
Blackwater	94/79	0.64	2,279	9.8
Choctawhatchee	280/201	0.27	12,033	204.8
Apalachicola	805/161	0.40	51,800	702.4
Ochlockonee	257/180	0.47	5,957	45.7
Suwannee	394/333	0.09	25,641	304.7
Hillsborough	88[2]	0.27	1,787	16.8

[1]The first number refers to the total length of the river, the second number refers to the length of the river in Florida.
[2]The total length of the Hillsborough River is in Florida.

bays and rivers that gulf sturgeon currently inhabit or historically inhabited. The ecosystems will be described from west to east and then north to south.

Pensacola Bay System
(Appendix Figure A2)

PENSACOLA BAY

Pensacola Bay, which lies between Escambia and Santa Rosa counties, has a surface area of 140 km^2 (Olinger *et al.*, 1975, cited in FDEP, 1998a). The Pensacola Bay system includes five interconnected estuarine bays (Pensacola, Escambia, Blackwater, East, Little Sabina) and Santa Rosa Sound (Northwest Florida Water Management District [NWFWMD], 1997).

Sediments from tributaries affect the mainstem rivers that feed Pensacola Bay by making the rivers shallow, which in turn restricts the flushing rates of the bay. Areas of Pensacola Bay have sediments that are severely contaminated from point and nonpoint sources, with as many as 40 chemicals at concentrations greater than recommended guidelines, especially in the bayous (United States Environmental Protection Agency [USEPA], 1999). Fish kills have occurred sporadically in the Pensacola Bay Basin, which contains the highest number of rare and imperiled fish species in the state of Florida (Hoehn, 1998). The Pensacola Bay system has also been adversely affected by the continuing construction of urban residential dwellings in the drainage basin (Purdum and Penson, 1998).

OCCURRENCES OF GULF STURGEON IN PENSACOLA BAY

A gulf sturgeon measuring 56 cm long was collected in Pensacola Bay in January 1978 (Collection Number 10319, FDEP, FDNR). Commercial fishers gillnetted a gulf sturgeon weighing 16 kg off Redfish Point in Pensacola Bay in December 1994 (Pensacola News Journal)[3]. Researchers collected and tagged six gulf sturgeon weighing 23.6–61.0 kg off the eastern portion of the bay in April 2000 (N. Craft, NW Florida Aquatic Preserves, FDEP, personal communication).

ESCAMBIA BAY

Escambia Bay is 93 km^2 in area (FDEP, 1998a). Water-quality problems have been documented in Escambia Bay since at least 1955, when bioassays indicated industrial waste discharges were affecting aquatic life in the bay (Murdock, 1955). Escambia Bay is the most highly stressed bay in the Pensacola system because of the high level of industrial discharges and the low level of natural circulation within the bay. The northern portion of the bay suffers from severe water-quality problems (*e.g.,* widely fluctuating dissolved oxygen levels and high total organic carbon, nitrogen, and phosphorus concentrations) and has the greatest potential for accumulating toxic compounds (NWFWMD, 1997; FDEP, 1998a). Dredging in the bay disturbs the sediments and causes severe oxygen depletion and massive fish kills (Wolfe *et al.,* 1988). The EPA has determined that point-source discharges, urban inputs, and agricultural runoff have adversely affected Escambia Bay, so the EPA is conducting a multiyear watershed risk-assessment evaluation to determine the bay's ecological status (FDEP, 1998a).

OCCURRENCES OF GULF STURGEON IN ESCAMBIA BAY

Although gulf sturgeon are known to migrate into Escambia Bay in the fall and winter (N. Craft, NW Aquat-

[3]USFWS. (Unpublished.) Gulf Sturgeon Status of Species Sept. 2000, Panama City, Florida.

ic Preserves, FDEP, personal communication), no recent information has been collected documenting their distribution within the bay.

BLACKWATER BAY

Blackwater Bay, with an area of 25.4 km^2, is located at the mouth of the Blackwater River, bordering Garcon Point, and has the lowest salinity of all the embayments in the Pensacola system (NWFWMD, 1990, cited in NWFWMD, 1997). This basin is considered fairly unaffected by anthropogenic sources and is classified as having good water quality (NWFWMD, 1997). However, residential development and erosion have adversely affected Blackwater Bay. Development and erosion need to be regulated and monitored so these factors do not further degrade water quality in the bay in the future (FDEP, 1998a). The construction of the Garcon Point Bridge, the new toll bridge connecting Garcon Point and Gulf Breeze, and the connector road to the north may also adversely affect sturgeon habitat in Blackwater Bay.

EAST BAY

Eglin Air Force Base's weapons test ranges, Hurlbert Field, and developments in Santa Rosa and Okaloosa counties drain into East Bay. The water quality in East Bay is deteriorating because Santa Rosa County is experiencing one of the fastest rates of human-population growth in the country. This rapid growth of population and expanded residential development has caused an increase in nonpoint-source pollutants within the bay (FDEP, 1998a).

SANTA ROSA SOUND

Santa Rosa Sound is a 109.8-km^2 lagoon located between Choctawhatchee and Pensacola bays (FDEP, 1998a). Stresses to the estuarine habitat from development and stormwater runoff are accelerating eutrophication rates in Santa Rosa Sound. Discharges from the wastewater treatment plants of Navarre and Pensacola beaches and runoff from several golf courses and spray irrigation areas, which have been treated with municipal wastes, have also adversely affected the water quality of the sound (NWFWMD, 1997).

RECENT OCCURRENCES OF GULF STURGEON IN SANTA ROSA SOUND

The USEPA reported that a 23-kg gulf sturgeon had washed up on the beach in Santa Rosa Sound near Navarre in 1988, and that one 91.4 cm in total length had washed up on the shoreline in Santa Rosa Sound near Navarre in January 2000 (F. Parauka, USFWS, personal communications).

SUMMARY AND NEEDED IMPROVEMENTS IN PENSACOLA BAY

The subbasins of the Pensacola Bay system are species-poor in terms of benthic invertebrate communities and have high levels of nutrients, bacteria, and sediments. Despite these problems, the subbasins have high numbers of endangered species and large populations of shellfish. Therefore, the NWFWMD is working with local governments to develop stormwater-management plans to decrease the sediment- and nutrient-loading caused by the urbanization surrounding Pensacola Bay (Purdum and Penson, 1998). Two land-acquisition programs could provide ways to deal with the water-quality deterioration in the Pensacola Bay system.

The Save Our Rivers and Preservation 2000 programs acquired 754 hectares of the Garcon Point ecosystem in 1991. Since 1991, an additional 554 hectares have been acquired, but an additional 1,550 hectares are still needed to protect the Garcon Point peninsula (NWFWMD, 1999). The wetlands of the peninsula are essential because they filter stormwater, provide a buffer that absorbs wave energy during storms, and prevent erosion of neighboring uplands. The peninsula is also susceptible to erosion and sedimentation as a result of off-road vehicle use and residential and commercial development (NWFWMD, 1998, 1999). The wetlands of Escribano Point, which lies between Eglin Air Force Base and Blackwater and East bays, provide stormwater filtration and buffer storm-induced erosion of adjacent uplands, and its 1,955 hectares are to be acquired by the NWFWMD to protect the area from development. Escribano Point will also act as a bridge between existing conservation areas—such as Garcon Point, Yellow River Marsh Aquatic Preserve, and Eglin Air Force Base—by forming a large corridor with a wide variety of wildlife habitats (NWFWMD, 1998, 1999).

RIVERS OF THE PENSACOLA BAY SYSTEM

The primary rivers flowing into the basin of the Pensacola Bay system are the Escambia, the Yellow, and the Blackwater rivers. These rivers are known as "blackwater rivers" because their water is dark and clear, flows from a surface source, has an acidic pH, and has a low level of dissolved minerals (Purdum and Penson, 1998). The primary problems in these rivers are bank erosion and river sedimentation. Florida plans to deal with these issues by acquiring and protecting lands bordering habitat essential for gulf sturgeon. Deadhead logging is the process of recovering submerged precut logs from aquatic systems. The removal of deadhead logs in these rivers may cause problems because the logs, which are embedded on the river bottom, form important habitats for invertebrates and juvenile fish. The logs also form deep holes in the streams, which provide the river depth important to gulf sturgeon. The FDEP Sovereignty Submerged Lands Use Agreement—Attachment B, Prohibited Waterbodies for Removal of Pre-cut Timber states that: "Recovery of pre-cut timber shall be prohibited in those waterbodies that are considered pristine due to water quality or clarity or where the recovery of precut timber will have a negative impact on, or be an interruption to, navigation or recreational pursuits."

ESCAMBIA RIVER

CURRENT PHYSICAL CONDITION

The Escambia River—148 km long, 87 km of which is located in Florida (Seaman, 1988)—is the largest river in the Pensacola Bay system (NWFWMD, 1997). After the establishment of industrial plants along the river in the middle 1970s, aquatic conditions in the river changed from healthy to stressed (USEPA, 1975). Most tributaries of the Escambia River appear to be threatened, and some are degraded (Hand, *et al.*, 1996). Gulf Power Company Incorporated discharges warm water into the river, which could make the water temperature as much as 6.7°C higher than it normally is during the summer months (N. Craft, NW Aquatic Preserves, FDEP, personal communication). The Monsanto Chemical Plant, which is also located on the river, has leaked polychlorinated biphenyl (PCB) into the Escambia River since 1969 (USEPA, 1975). Nonpoint-source pollutants, such as agricultural runoff, sedimentation, and gravel mining operations, have also seriously affected the river basin (Hand *et al.*, 1996; Livingston *et al.*, 1988). A decline in fisheries in the river has been attributed to sedimentation, turbidity, and pesticides. However, the past 20 years have been a period of recovery (FDEP, 1998a). In 1984, the Save Our Rivers Program acquired 7,280 hectares in an effort to preserve the Escambia River Basin (NWFWMD, 1999).

GULF STURGEON OCCURRENCES IN THE ESCAMBIA RIVER

Recreational anglers have reported that prior to 1980, they would see as many as ten gulf sturgeon jump at one time in the river. Now it is rare to see even one sturgeon jump (Reynolds, 1993). A common place for collecting gulf sturgeon in the Escambia River is below the Route 184 bridge. From May through September 1995, 11 gulf sturgeon weighing 0.7–55 kg were collected (F. Parauka, USFWS, personal communication), and in September 1998, a gulf sturgeon weighing 30 kg was captured (F. Parauka, USFWS, personal communication). In April–May 2000, three gulf sturgeon weighing 20.4–41.4 kg were collected and tagged by researchers (N. Craft, NW Florida Aquatic Preserves, FDEP, personal communication).

IMPROVEMENTS TO ENHANCE HABITAT

Recovery of deadhead logs is prohibited in the Escambia River from Chumuckla Springs to a point 4 km south of the springs; the prohibition of log removal in this area will help protect gulf sturgeon habitat. The Escambia Soil and Water Conservation District, West Florida Regional Planning Council, Bay Area Resource Council, FDEP, and Escambia Neighborhood and Environmental Services have jointly proposed a program to reduce sediment-loading into the river. The North Escambia Gully Control Environmental Quality Incentives Program Geographic Priority Area Plan (2000 EQUIP Proposal) is a cooperative five-year program to reduce sediment inputs from gullies that are causing severe damage to streams and wetlands. The conservation practices to be implemented for the Escambia Basin include (1) gully-control structures, (2) establishment of permanent vegetation along the river bank, (3) fencing, (4) diversions, (5) conservation buffers, and (6) underground outlets (Collar, 2000). Pesticide runoff feeding into the Escambia River from agricultural lands needs to be limited. FDEP will work with landowners and farmers to see that this plan is implemented in the basin.

YELLOW RIVER

CURRENT PHYSICAL CONDITION

The Yellow River originates in Alabama and travels 150 km before discharging into Blackwater Bay (FDEP, 1998a). The Yellow River has some of the most pristine water in Florida, and its high gradient produces a swift flow of 62 m^3/sec (FDEP, 1998a). The river is fed primarily by rain runoff and is highly susceptible to pollution from land-use activities (NWFWMD, 1998).

Most of the habitat and nutrient changes in the Yellow River have occurred from the Florida line southward and have been the result of development, road construction, and logging. According to a local family, the water levels of a tributary above the Yellow River have dropped from 6 m to 1 m during the past 20 years and the water has become muddy (D. Ray, FDEP, personal communication). The Yellow River basin has also been degraded by nonpoint-source pollution (NWFWMD, 1994, cited in NWFWMD, 1997; Hand *et al.*, 1996).

GULF STURGEON OCCURRENCES IN THE YELLOW RIVER

Landings of gulf sturgeon in the Yellow River were occasionally reported prior to the 1984 moratorium on sturgeon fishing in Florida (J. Barkuloo, USFWS [retired], personal communication). Eighteen wild sturgeon weighing 5.8–63.6 kg were captured, tagged, and released in the Yellow River in 1993 by the USFWS (F. Parauka, USFWS, personal communication). Four gulf sturgeon measuring 61–122 cm in total length were collected at the mouth of the Yellow River in October 1997 (T. Slack, University of Mississippi, personal communication). From September through October 1997, biologists sampling below Boiling Lake collected 10 gulf sturgeon weighing 11.5–47.7 kg and tagged them with external sonic tags (F. Parauka, USFWS, personal communication). In July 1998, biologists electrofished a 30-kg gulf sturgeon below Andalusia, Alabama (K. Weathers, Alabama Department of Natural Resources, personal communication). In September 1999, researchers collected 8 gulf sturgeon (11.2–49.5 kg) below Boiling Lake (F. Parauka, USFWS, personal communication), and in April–May 2000, researchers collected and tagged 10 gulf sturgeon weighing 15.9–80.0 kg (N. Craft, NW Aquatic Preserves, FDEP, personal communication).

Because sporadic empirical data on the abundance or occurrence of sturgeon in the Yellow and Escambia river systems exist, the FWC provided funds to the FDEP's NW Aquatic Preserves to study the movement of gulf sturgeon migrating up these rivers. The purpose of that study is to increase scientists' understanding of the general migration patterns of gulf sturgeon within the Pensacola Bay system and to locate areas where sturgeon could spawn within the Yellow and Escambia rivers (Appendices B, C).

IMPROVEMENTS TO ENHANCE HABITAT

Logging and road construction in the Yellow River Basin need to be reduced to prevent continued shoreline degradation, erosion of the banks, and siltation and shallowing of the river bed. Also, nutrient loads generated by agriculture and development need to be reduced. From 1992 to 1994, the NWFWMD acquired 3,303 hectares in the Yellow River Basin, but 4,791 hectares of bordering and buffering lands surrounding the basin must also be acquired to ensure that the water resources of the Yellow River Basin are effectively protected and managed (NWFWMD, 1999).

Construction of six new water wells near Crestview, Florida, has been proposed. Water would be piped to southern Okaloosa County, where the existing wells have been experiencing declining water levels and saltwater intrusion. The digging of these wells could affect the Floridian Aquifer, which lies several hundred feet underground, as well as surface aquifers that contribute to springs along the Yellow River (D. Fruge, USFWS, Gulf Coast Fisheries Coordination Office, Ocean Springs, Mississippi, personal communication).

A group in Crestview, Florida, proposed the construction of a 4,047-hectare reservoir on the Yellow River near Milligan, Florida, as an alternative to drilling (Henderson, 2000). The reservoir would provide a long-term solution to Okaloosa County's water problems, bring in economic development to the northern part of the county, and provide flood control for the Yellow River flood plain (Stewart, 2000). This project is in only the initial planning stages, and although it would provide increased fresh water to residents, it would affect the habitat that gulf sturgeon use to migrate upriver to Alabama to spawn.

BLACKWATER RIVER

CURRENT PHYSICAL CONDITION

The Blackwater River originates in Alabama and flows 107 km before entering Blackwater Bay in northwestern Florida (FDEP, 1998a). The river drains 1,594 km^2 (Hand *et al.*, 1996) of acidic flatwoods, which gives the water a reddish-brown color. The Blackwater receives discharges of groundwater from an aquifer and has moderate annual variations in stream flow (Purdum and Penson, 1998). Because most of the normal input to the river is groundwater, river water temperatures are moderate throughout the year (Beck, 1965, cited in Seaman, 1988). The Blackwater River also supports more species of benthic invertebrates than are found in most other rivers of Florida (Beck, 1973).

Deadhead logs help to maintain the character and health of the river (V. Compton, TNC, personal communication). Over the past 20 years, the removal of this large, woody debris has changed the river flow from pools and riffles to a shallow, wide, slow-flowing river. The spreading of the river has also caused erosion of bank vegetation. The U.S. Forest Service has reported sediment build-up as deep as 1.2 m in some areas of the Blackwater River (Streater, 1999). Shallow water also increases the possibility of fish kills, because it heats up more rapidly during summer months and warmer water does not hold as much oxygen as cooler water does. Sediment run-off also covers exposed tree roots along the banks of rivers and smothers the fish eggs and benthic organisms found there (D. Ray, FDEP, personal communication).

Currently, the Blackwater River receives most of its nonpoint-source pollutants from urban development and land runoff. Urban development and road construction have caused increased erosion, flooding, and sedimentation in the watershed (NWFWMD, 1997). The nutrients from agriculture and silviculture (Hoehn, 1998) and pesticides from cattle operations and fruit and nut production (FDEP, 1998a) contribute to poor water quality in the Blackwater River Basin. Other adverse effects resulting from human activities on the river include wetland filling and water-flow alterations caused by groundwater withdrawal (Purdum and Penson, 1998). Increase in development, increase in recreation, cutting new roads, construction, and cutting trees also result in loss of bank vegetation and increased erosion (V. Compton, TNC, personal communication).

In the Blackwater River State Forest, the large extent of roads (more than 885 km) located along the bank of the river and the large number of vehicle-access points on the rivers and streams (more than 70 along the Blackwater River itself) create severe erosion and sedimentation problems (Compton, 1998). Also, uncontrolled river access causes washouts, destruction of seepage-slope communities, disruption of riverine vegetation, and flooding problems along the rivers and streams that surround the forest (Compton, 1998). Erosion of or sedimentation on river banks also destroys habitat by killing vegetation, destroying the natural wetlands, widening creeks and rivers via loss of side banks, increasing the expenses of road maintenance, and providing illegal dumping sites. According to F.S. 430.061 (27), the Blackwater River and Blackwater River State Park are worthy of special protection as “Outstanding Florida Waters” because of their natural attributes (FDEP, 1998a). This protection may help protect sturgeon habitat.

RECENT OCCURRENCE OF GULF STURGEON IN THE BLACKWATER RIVER

Commercial fishing for sturgeon in the Blackwater River began in 1901 (Huff, 1975) and ended with the moratorium in 1984. Three gulf sturgeon weighing 5–12 kg were collected in the Blackwater River in March 1991 during a Florida Game and Freshwater Fish Commission (GFC) striped bass netting project (USFWS and GSMFC, 1995).

IMPROVEMENTS TO ENHANCE HABITAT

Threats to the water quality in the Blackwater River include gully erosion, run-off of fertilizers and pesticides to the upper basins, and accelerating residential development in the lower part of the watershed (West Florida Regional Planning Council, 2000). Most of the erosion and sedimentation problems in the Blackwater River are a result of vehicles driving off established roads. Therefore, vehicles need to be redirected to designated roads and parking areas (Compton, 1998). Enforcement needs to be increased in forested areas along the Blackwater River to prevent people without permits from cutting trees and removing logs (V. Compton, TNC, personal communication). Erosion-control measures are being used to restore the highly sloped banks bounding the Blackwater River (Compton, 1998). The NWFWMD has proposed acquiring 7,835 hectares to protect this fragile river basin (NWFWMD, 1999). If the NWFWMD acquires this land and conditions improve within the river basin, a more suitable habitat will exist for gulf sturgeon, which may help the number of sturgeon to increase.

SUMMARY AND NEEDED IMPROVEMENTS IN THE PENSACOLA SYSTEM RIVERS

The biggest habitat threat to Florida Panhandle rivers is increased sedimentation from the removal of logs and construction of dirt roads (D. Ray, FDEP, personal communication). FDEP is responsible for issuing regulatory permits in the area covered by the NWFWMD. Therefore, FDEP needs to work with industrial plants, road construction companies, and landowners to develop a plan to reduce both point-source pollutants from industrial plants and sediments from unpaved roads.

In a study in which 33 streams in the Pensacola Bay system were bioassessed by the West Florida Regional Planning Council (2000), 3 were healthy, 1 was suspect, and 29 were impaired. D. Ray, FDEP, believes that the 29 streams were impaired principally because of habitat destruction (Ray, 1999). The habitat has been destroyed by sedimentation mainly from upland erosion and stream bank erosion. Sediments from the banks smother riverine habitats, where macroinvertebrates, primary prey for fish, live. As the bank habitat degrades, invasive exotic species, such as Chinese privet, encroach upon the disturbed area. In and near areas where exotic plants have become dominant, aquatic macroinvertebrates are severely reduced, thereby changing the whole ecosystem and displacing resident fish as well.

With so many streams impaired by sedimentation, high fecal-coliform counts, and excessive nutrients, much needs to be done to improve the sturgeon habitat in Panhandle river systems. Cooperation among government agencies and farm communities to prevent nonpoint-source pollution is less costly than enforcement actions resulting from a water-quality violation are (West Florida Regional Planning Council, 2000). The intense rainfall and sandy soils, lack of bedrock, and degree of slope in the area’s topography result in increased erosion and gully formation. A knowledgeable hydrologist and restoration dollars are required to prevent further sedimentation in Panhandle rivers and the erosion of their banks (D. Ray, FDEP, personal communication). Efforts of local, county, and state governments are necessary to dredge streams, plant native bank vegetation, and implement Best Management Practices (BMPs). Unless habitat is restored, there is little chance of enhancing the gulf sturgeon populations in these Panhandle rivers.

Choctawhatchee Bay System
(Appendix Figure A3)

CHOCTAWHATCHEE BAY

CURRENT PHYSICAL CONDITION

Choctawhatchee Bay is nearly 48 km long and 4.8 km wide and has a surface area of more than 34,803 hectares, making it the third-largest estuarine system on the Florida gulf coast (Seaman, 1988). Before the entrance from the gulf to Destin was created in the late 1920s, Choctawhatchee Bay was a freshwater system, and the only way for gulf sturgeon to migrate to the Gulf of Mexico was through Santa Rosa Sound. The Choctawhatchee Bay basin has the second-highest number of rare and imperiled fish in the state of Florida (Hoehn, 1998). The overall water quality of the basin has been classified as "good" by Hand *et al.* (1996), but the current health of the bay is severely threatened by development in the surrounding watershed. Development in the northern part of the bay is minimal because of the presence of Eglin Air Force Base. However, residential hotels, condominiums, and urban run-off are causing water-quality problems along the southern shores of the bay.

Most enrichment of Choctawhatchee Bay by anthropogenic nutrients occurs as a result of nonpoint-source pollution (NWFWMD, 1996b). Pollutants from the watershed that are increasingly causing problems include sediments washed down from unpaved roads and croplands and toxic contaminants from animal wastes, septic tanks, marinas, golf courses, and urban stormwater runoff (Barnett and Teehan, 1989, cited in FDEP, 1998c). These toxic contaminants build up in the sediment layers, harming water quality and destroying benthic communities. When benthic communities are destroyed, the trophically higher animals, such as fish and birds, are harmed by the change in or lack of food (FDEP, 1996). Sedimentation in the river from silviculture and dirt roads has also changed both the physical characteristics of the bay and the sediment quality and quantity (FDEP, 1996). R. Heard, University of Southern Mississippi (USM), Gulf Coast Research Laboratory, is working on studies (Appendices B, C) to assess the macroinvertebrate faunal assemblages of Choctawhatchee Bay as they relate to the feeding behavior, seasonal occurrence, and spatial distribution of gulf sturgeon.

GULF STURGEON OCCURRENCES IN CHOCTAWHATCHEE BAY

Choctawhatchee Bay provides an important habitat for gulf sturgeon because a large number of sturgeon overwinter there (Fox and Hightower, 1998; Fox *et al.*, 2000). Most gulf sturgeon monitored in this bay prefer shoreline habitats, sandy substrates, low salinities, and water depths of less than 3 m (Fox *et al.*, 2000). In the bay, gulf sturgeon forage principally on shrimp before initiating their upstream migrations (R. Heard, USM, Gulf Coast Research Laboratory, personal communication). A USFWS study of the bay found that 78% of tagged subadult (age 4–7) gulf sturgeon overwintered in areas along sandy shorelines that lack seagrass and have water depths of less than 3.5 m and salinities of less than 6.3 ppt (USFWS, 1998). In contrast, the study suggested that as many as 40% of tagged gulf sturgeon adults (of which 88% were females) could have spent extended winter periods in the Gulf of Mexico (Fox and Hightower, 1998). This percentage is uncertain because sturgeon were not tracked in the bay.

Four gulf sturgeon measuring 41.2–81.9 cm were collected by FDEP in April 1993 in Jolly Bay at the northeastern end of Choctawhatchee Bay (D. Peters, FMRI, Ft. Walton, personal communication). Potak *et al.* (1995) collected fifty gulf sturgeon in the eastern part of Choctawhatchee Bay off the mouths of the Indian, Cyprus, and Choctawhatchee rivers in April 1992; 25 of these fish, weighing 2.5–72.7 kg, were then equipped with radio tags. Fifty-two gulf sturgeon were collected off the south shore of Choctawhatchee Bay near Live Oak Point in March and April 1996; 37 of these sturgeon, weighing 9.5–88.27 kg, were equipped with radio and/or sonic tags (Fox and Hightower, 1998). A gulf sturgeon weighing 6.8 kg was washed up on the Gulf of Mexico side of the beach near Destin in February 1999; the sturgeon had been collected previously in the eastern portion of Choctawhatchee Bay near the mouth of Cyprus River in April 1994. Several harmful algal blooms (red tides) occurred in Choctawhatchee Bay from late November 1999 to early January 2000, and these blooms are suspected to have caused the 20 documented gulf sturgeon mortalities (F. Parauka, USFWS, personal communication).

According to a study by Fox *et al.* (North Carolina State University [NCSU], personal communication), gulf sturgeon in Choctawhatchee Bay principally occupy low-relief shallow shoreline areas composed of sand substrate. Individual sturgeon move over these areas until they encounter sufficient prey, at which time they stop to forage for prolonged periods. Although seagrass habitats typically support higher levels of invertebrate abundance and diversity than sand habitats do (Livingston, 1986; Heck *et al.*, 1995), gulf sturgeon tracked by Fox *et al.* (NCSU, personal communication) did not frequent seagrass habitats. Also, because the digestive tracts of two gulf sturgeon that died during netting operations were full of ghost shrimp

(*Lepedophthalmus louisianensis*) and an associated commensal shrimp (*Leptalpheus forceps*), these researchers hypothesized that gulf sturgeon in Choctawhatchee Bay fed principally on these shrimp (Fox *et al.,* NCSU, personal communication). A study currently being conducted of benthos distribution in Choctawhatchee Bay supports this hypothesis (R. Heard, USM, Gulf Coast Research Laboratory, personal communication; Appendices B, C).

CHOCTAWHATCHEE RIVER

CURRENT PHYSICAL CONDITION

Choctawhatchee Bay's main freshwater input is the Choctawhatchee River. The 280-km (201 km in Florida) river originates in Alabama and flows through the Florida Panhandle (Seaman, 1988). It is a major alluvial river and has the third-largest discharge of any river in Florida (Livingston *et al.,* 1991). Because the mainstem river is not impounded and principally drains swamps, forests, and agricultural lands, it carries a heavy load of suspended solids and is probably the most turbid of Florida's rivers (Seaman, 1988).

The Choctawhatchee River has been moderately degraded by agricultural runoff (a large portion of which is from Alabama), and several tributaries have been polluted by domestic or industrial discharges (Purdum and Penson, 1998). Shoreline development has increased erosion and reduced bank vegetation. The river also receives nutrients, bacteria, pollutants, and sediments from nonpoint and point sources along the river's tributaries (Florida Department of Environmental Regulation [FDER], 1990; NWFWMD, 1996b). The coliform bacteria in the water have infected fish, and high levels of bacteria have prompted the release of fish-consumption advisories. These high levels of bacteria were cited as major concerns by the 1998 Florida 305(b) Water Quality Assessment Report (FDEP, 2000a) and the 1996 Florida 305(b) Water Quality Assessment Report (FDEP, 1996).

The Florida 305(b) Water Quality Assessment report uses a watershed approach to evaluate the chemical and biological components of Florida's surface waters, ground waters, and wetlands. The 305(b) report also describes the existing programs to protect the quality of Florida's waters. Information from the 305(b) report is reviewed and water bodies are placed on the federal 303(d) list. Under Section 303(d) of the Clean Water Act, every two years every state must identify water bodies that do not meet the minimum water-quality standards. Florida's 303(d) report identifies hundreds of impaired water-body segments; the four most common problems associated with these water segments are coliforms, nutrients, oxygen-demanding substances, and turbidity.

GULF STURGEON OCCURRENCES IN THE CHOCTAWHATCHEE RIVER

Gulf sturgeon are still widespread in the Choctawhatchee River. Three gulf sturgeon, weighing 17–26 kg, were collected in the upper Choctawhatchee River below its confluence with the Pea River at Geneva, Alabama, in August 1991 (F. Parauka, USFWS, personal communication). A gulf sturgeon weighing 13 kg was caught by an angler downstream from Caryville, Florida. During the summer, subadult and adult gulf sturgeon have been periodically collected in gillnets and tagged by biologists since 1988 between Howell Bluff and Rocky Landing (F. Parauka, USFWS, personal communication). A total of 450 gulf sturgeon weighing 0.75–76.6 kg were gillnetted, tagged, and released by biologists in the lower Choctawhatchee River during a 16-day period from mid-October to mid-November 1999. The population of sturgeon longer than 60.9 cm was estimated to be approximately 3,000 fish (USFWS, 1999). The population study continued during October–November 2000 and will continue in 2001.

IMPROVEMENTS TO ENHANCE HABITAT

Between 1985 and 1997, the NWFWMD acquired 214,510 hectares in the Choctawhatchee River basin through the Save Our Rivers and Preservation 2000 programs (NWFWMD, 1999). Both the NW Florida Aquatic Preserves and the FDEP NW District Ecosystem Restoration Section are working on shoreline-restoration projects intended to prevent erosion in the Choctawhatchee basin (FDEP, 1996). Because 70% of sediments in the Choctawhatchee basin system are attributed to dirt-road construction, roadside vegetation should be maintained and retaining walls and headwalls should be constructed along steep slopes in order to decrease the sediment runoff from unpaved roads in the vicinity of the basin system in Florida. The maintenance of unpaved roads in southeastern Alabama is also important because the Choctawhatchee, Pea, and Yellow rivers, which originate in Alabama, cross the state line and flow directly into Florida rivers (Choctawhatchee, Pea, and Yellow Rivers Watershed Management Authority, 2000).

Poly Engineering in Dothan, Alabama, funded by the Choctawhatchee, Pea, and Yellow Rivers Watershed Management Authority, produced a manual and video for engineers on proper grading of dirt roads in order to reduce sediments in the Choctawhatchee basin. Training sessions for engineers have been held in eight counties in Alabama. The results of this program will be evaluated to determine whether people are following guidelines (G. Carmody, USFWS, personal communication).

Prohibiting removal of deadhead logs and permitting removal of a lowhead dam could also increase habitat for gulf sturgeon in the Choctawhatchee River. According to the FDEP Sovereignty Submerged Lands Use Agreement—Attachment B, Prohibited Waterbodies for Removal of Pre-cut Timber, the Choctawhatchee River is protected from deadhead log removal in the 4.8-km stretch south of the Alabama line during the months of March, April, and May, which is when gulf sturgeon migrate upriver. Also, according to F. Cross (FWC, Panama City, personal communication), removal of the lowhead dam in the Pea River, a branch of the Choctawhatchee in Alabama, could open up additional spawning habitat for gulf sturgeon.

St. Andrew Bay System
(Appendix Figure A4)

ST. ANDREW BAY

CURRENT PHYSICAL CONDITION

The St. Andrew Bay drainage basin encompasses approximately 3,500 km^2 and includes St. Andrew, West, North, East, and St. Joseph bays and St. Andrew Sound (Wolfe *et al.,* 1988). The 2,927-km^2 drainage basin feeding St. Andrew Bay is entirely within Florida (USDOC, 1997) and is the only major estuarine drainage located entirely within the Florida Panhandle. A dam, constructed in 1962 across North Bay, prevents anadromous fish from migrating upriver (Smith and Clugston, 1997). Because of the low levels of freshwater inflow, a deep basin, and the influence of Gulf of Mexico water, St. Andrew Bay is characterized as a relatively deep, clear-water, high-salinity system (BEST [Bay Environmental Study Team] and FDEP, 1998).

In total acreage, the St. Andrew Bay system contains the largest seagrass stock in Florida's panhandle (Wolfe *et al.,* 1988). Over the past 40 years, there has been a 17% decline in the total acreage of seagrass in St. Andrew Bay (BEST and FDEP, 1998). Factors that can reduce the extent or quality of the seagrass beds include increased turbidity, dredging and filling, boat-propeller damage, sediment contamination, nitrification of the water column, and local sustained decreases in salinity (BEST and FDEP, 1998). The St. Andrew Bay system has also experienced many of the impacts common to Florida estuaries, such as urban stormwater runoff and other nonpoint sources of pollution, domestic and industrial point-source pollution, and sedimentation. These factors have caused habitat loss and degradation of the bay (BEST and FDEP, 1998).

The USFWS, Panama City Field Office, conducted an extensive study of the quality of sediments in the St. Andrew Bay system (BEST and FDEP, 1998). The deeper sediments of the bay and its tributary bayous are particularly prone to chemical contamination because they are fine-grained and have high levels of carbon. Because harmful chemicals released into the bay readily associate with these types of sediments, high concentrations of heavy metals and organic contaminants can quickly accumulate in the sediment (BEST and FDEP, 1998). An evaluation of dredged material from stations in St. Andrew Bay showed that these sediments had higher concentrations of contaminants than reference sediments did (USDOC, 1997). Also, significantly higher levels of polycyclic aromatic hydrocarbons (PAHs), pesticides, and PCBs were measured in clams (*Macoma nasuta*) than were present in reference sediments, which shows that St. Andrew Bay clams are bioaccumulating the contaminants (Mayhew *et al.,* 1993). St. Andrew Bay is unique of all Florida embayments because no major river flows into the system (BEST and FDEP, 1998). Because of its depth and marine-like conditions, St. Andrew Bay may provide winter feeding habitat of moderate value to sturgeon. Sturgeon access to the bay has been increased by the intracoastal waterway, which connects St. Andrew Bay to Choctawhatchee Bay to the west and to the Apalachicola River to the east via Lake Wimico (Brim, 2000).

GULF STURGEON OCCURRENCES IN ST. ANDREW BAY

In a gillnet survey, researchers collected and released one 122-cm gulf sturgeon outside the mouth of Lake Van Vac in March 1986 (M. Brim, USFWS, cited in USFWS and GSMFC, 1995). A gulf sturgeon weighing 3.9 kg was captured in March 1999 by NMFS biologist Bill Walling (F. Parauka, USFWS, personal communication). Additional gulf sturgeon have been sighted within the St. Andrew Bay system (Reynolds, 1993), and Hoehn (1998) listed gulf sturgeon as a component of the St. Andrew Bay system. Reports of sturgeon in the St. Andrew Bay ecosystem are sparse, but their occurrence there should be considered in the overall management of the ecosystem (BEST and FDEP, 1998).

IMPROVEMENTS TO ENHANCE HABITAT

According to the BEST Public Outreach and Education Committee, resource managers hope to accomplish the following by restoring the St. Andrew Bay ecosystem:

- to maintain existing water quality by emphasizing the treatment of stormwater runoff;
- to reduce the fragmentation and loss of habitat caused by random development activities;

- to reduce wetland losses caused by development;
- to protect the quality and quantity of water entering the bay from its principal tributaries;
- to restore seagrass beds;
- to maintain ecosystem biodiversity; and
- to restore water bodies or segments of water bodies (BEST and FDEP, 1998).

ECONFINA CREEK

CURRENT PHYSICAL CONDITION

The largest inflow to the St. Andrew Bay system comes from Econfina Creek, a predominately groundwater-fed stream (Musgrove *et al.,* 1964). Econfina Creek travels 56 km from its headwaters to North Bay, drains 774 km^2 (SRWMD, 1999), and is considered to be one of the most pristine waterways anywhere in Florida. The high-quality groundwater of the creek also supplies Panama City's Deer Point Lake Reservoir. This waterway may have been important gulf sturgeon habitat in the past, but a dam was constructed in 1962 above North Bay, forming Deer Point Lake and reservoir, prevents anadromous fish from migrating. The "Rivers of the Big Bend" purchase in 1996 put 63% of the total length of the Econfina into a protected, continuous corridor that contains 3,420 hectares and 71 km of river frontage (SRWMD, 1999).

GULF STURGEON OCCURRENCES
IN ECONFINA CREEK

In May 1961, four gulf sturgeon, ranging in length from 173 to 201.5 cm, were collected by biologists in Bear Creek, a tributary of Econfina Creek (USFWS and GSMFC, 1995), but no reports of gulf sturgeon have been documented in this tributary since the dam has been in place.

IMPROVEMENTS TO ENHANCE HABITAT

Between 1992 and 1994, the NWFWMD acquired 15,095 hectares of the Econfina Creek basin, but another 7,047 hectares need to be purchased to fully protect the watershed (NWFWMD, 1999). Residential development along Econfina Creek poses a significant threat to the water quality of the aquifer, Econfina Creek, and the public-water-supply reservoir. Therefore, land purchases proposed by the NWFWMD along Econfina Creek include several spring-run streams that contain imperiled biological communities (NWFWMD, 1998, 1999) and could provide important sturgeon habitat if the dam is removed or if a structure facilitating fish passage allows gulf sturgeon to successfully pass up and down river.

Apalachicola Bay System
(Appendix Figure A5)

APALACHICOLA BAY

CURRENT PHYSICAL CONDITION

The Apalachicola Bay system, a highly productive lagoon-and-barrier-island complex, encompasses 54,910 hectares (549 km^2) and consists of the bay proper, East Bay, St. George's Sound, Indian Lagoon, and St. Vincent Sound. The Apalachicola Bay system connects with the Gulf of Mexico through several passes (Seaman, 1988). Submergent aquatic vegetation is found on less than 7% of the bay bottom because high turbidity within the bay limits the depth of light penetration and is probably the main factor limiting growth of submerged macrophytes (Livingston, 1980, cited in Seaman, 1988). Apalachicola Bay has good water quality with the exception of localized pollution from fish houses and marinas (Purdum and Penson, 1998). Commercial dockside seafood landings, mostly oysters and shrimp, typically yield $12 million to $16 million annually (FDEP, 1998b). Apalachicola Bay also supports Florida's largest commercial oyster fishery (Purdum and Penson, 1998).

GULF STURGEON OCCURRENCES
IN APALACHICOLA BAY

In March 1987, a gulf sturgeon weighing 34 kg was captured, tagged, and released in Apalachicola Bay north of the U.S. Highway 98 bridge. In November 1989, a commercial shrimp fisher caught a gulf sturgeon that weighed 34.5 kg (F. Parauka, USFWS, personal communication). Incidental captures of gulf sturgeon by commercial shrimpers and gill-net fishers have been reported by Swift *et al.* (1977, cited in Wolfe *et al.,* 1988) and by Wooley and Crateau (1985). F.A.C. 68B-31.018 closes 10,522 hectares of Apalachicola Bay-St. Vincent Sound, 526 hectares of St. George Sound, and 20,072 hectares of Ochlockonee Bay to shrimping year-round. The same statute also provides for seasonal closures of an additional 2,630 hectares in Apalachicola Bay-St. Vincent Sound (March 1–May 31) and an additional 3,480 hectares in St. George Sound (September 15–December 31). These closures may help protect gulf sturgeon populations.

APALACHICOLA RIVER

CURRENT PHYSICAL CONDITION

The Apalachicola River, 161 km long, is larger in area than any other river on the gulf coast of Florida (Koefoed and Gorsline, 1963 cited in FDEP, 1998b) and has a larger volume of water (Wooley and Crateau, 1982) and volume of discharge (Seaman, 1988) than any other river in Florida. The Apalachicola River basin is part of the larger Apalachicola-Chattahoochee-Flint river system, which is 805 km long and drains parts of Georgia, Alabama, and Florida (Seaman, 1988). The water quality in the Florida portion of the Apalachicola River basin is good because of the undeveloped nature of the basin, the retention of pollutants in upstream reservoirs, and the sandy river bottom (NWFWMD, 1996a).

The River and Harbor Acts of 1945 and 1946 authorized the United States Army Corps of Engineers (USACOE) to construct four major lock-and-dam complexes within the Apalachicola River drainage basin. The first, Jim Woodruff Lock and Dam (JWLD), constructed in 1957, is located on the Apalachicola River at the Florida-Georgia state line, and it appears to completely prevent gulf sturgeon upstream of the dam from migrating downstream (Smith and Clugston, 1997). Wooley and Crateau (1985) estimated that the construction of the JWLD restricted gulf sturgeon to only 172 km of the river habitat that was formerly available to them. Additional suitable gulf sturgeon habitat is located upstream from the JWLD on the Flint and Chattahoochee rivers. The success rate of gulf sturgeon recolonization is limited in the Apalachicola River because the only spawning habitat accessible to sturgeon is located at the base of the JWLD. Anecdotal sightings indicate that the base of the dam was a great place for fishing, and sturgeon could easily be hooked or snagged as they were laying their eggs (Reynolds, 1993).

At least 18 structures, including USACOE's 4 dams, private hydroelectric dams, and other man-made structures now block the Apalachicola basin rivers (Wooley and Crateau, 1985). Before the construction of these structures, anadromous fish had more than 1,018 km of unrestricted river for migration and spawning (U.S. Study Commission, 1963, cited in Wooley and Crateau, 1985). Below Lake Seminole, much of the Apalachicola River is dredged periodically, and rock shoals have been removed to maintain a navigation channel for barge traffic (Bass and Cox, 1985). When the Apalachicola River was first dredged, the dredged gravel was used to build dams. During these modifications to the river channel, large sections of rock habitat were removed and additional habitat was smothered with sediments, thus limiting suitable spawning substrate for sturgeon.

The Apalachicola River basin has the second-highest numbers of rare and imperiled fish of any river basin in Florida (Hoehn, 1998). The basin's steep slopes have elevated levels of turbidity, suspended solids, and bacteria, and the low-volume water flows and increasing levels of pollutants have caused nutrient-rich conditions. In the lower river, silviculture and agriculture runoff contribute to eutrophication through nonpoint-source pollutants and sediments. Changes to the river have significantly affected the ecosystem and the overall biological productivity of the basin (Leitman *et al.*, 1991).

Competition for water between residents of the city of Atlanta and those of the rest of Georgia, Alabama, and Florida is a continuing problem. Discussions are ongoing between managers and policymakers regarding how to allocate water to parts of the Apalachicola, Chattahoochee, and Flint river systems. Diverting water from its natural river course causes changes in the river-bed hydrography and water flow, hence restricting habitat for sturgeon. The NWFWMD is assessing the freshwater needs of the Apalachicola river system to identify the minimum water flows required to sustain the current levels of productivity of the river and bay ecosystem (Purdum and Penson, 1998).

GULF STURGEON OCCURRENCES IN THE APALACHICOLA RIVER

Sturgeon fishing began in the Apalachicola system in 1898 (Huff, 1975). In 1901, according to a report of the U.S. Commission on Fish and Fisheries (1902, cited in Wooley and Crateau, 1985), the Apalachicola River supported the largest and most economically important sturgeon fishery in Florida. A. Carr (Caribbean Conservation Corps, personal communication) noted that 32 families fished commercially for gulf sturgeon in the middle 1940s. The sturgeon commercial fishery was profitable until the late 1950s. Most commercial sturgeon fishing ended in the 1970s, when harvest levels of sturgeon fell in Florida and competition from Russian sturgeon imports increased (NWFWMD, 1996a).

A hook-and-line sport fishery developed at the base of JWLD beginning in August 1962 (Burgess, 1963, cited in Huff, 1975). Sport fishing for gulf sturgeon in the spring and fall in some of the deeper holes in the Apalachicola River produced sturgeon weighing up to 73 kg (Tallahassee Democrat, 1958, 1963, 1969, all cited in USFWS and GSMFC, 1995). In the summer, gulf sturgeon in the Apalachicola River occupy the dam tailrace and spillway basin and the sand and gravel substrate in depths of 6–12 m immediately downstream from the JWLD (Wooley and Crateau, 1985).

Biologists at the USFWS's Panama City field office have monitored the Apalachicola River gulf sturgeon population since 1979, and during 1979–1999, more than 500 gulf sturgeon were collected and tagged in the Apalachicola River below the JWLD (F. Parauka, USFWS, personal communication). In 1998, 76 and in 1999, 103 gulf sturgeon were collected and tagged below the JWLD, and the population was estimated to be 270 in 1998 and 321 in 1999 (USFWS 1998, 1999).

THE BROTHERS RIVER

The Brothers River, a tributary of the Apalachicola, is located 32 km upstream of Apalachicola Bay. The Brothers River is the last large tributary of the Apalachicola above the influence of saltwater and serves as an important staging area in which gulf sturgeon can acclimate to the change from salt to fresh water and vice versa.

GULF STURGEON OCCURRENCES IN THE BROTHERS RIVER

Sturgeon remain in the Brothers River for an average of twelve days before migrating up the Apalachicola River to the base of the JWLD to spawn (Wooley and Crateau, 1985; Odenkirk, 1989). In November 1990, nine gulf sturgeon weighing 1–40.9 kg were collected in gillnets below Bearman Creek (F. Parauka, USFWS, personal communication). During a study conducted from June through September 1999, 71 gulf sturgeon were collected in gillnets, tagged, and released above Brickyard Cut-off (F. Parauka, USFWS, personal communication).

IMPROVEMENTS TO ENHANCE HABITATS OF THE APALACHICOLA AND BROTHERS RIVERS

The JWLD blocks the migration of gulf sturgeon and has eliminated all but 22% of their historical riverine habitat (USFWS and GSMFC, 1995). In addition to eliminating spawning habitat, the dam has altered river flows and temperatures from those that are necessary for successful sturgeon migration. Because habitat necessary for spawning has been limited, the first priority for restoring gulf sturgeon throughout the Apalachicola River system is to enable fish to move upriver past the dam in the spring and back downriver below the dam in the fall. Areas with water deeper than 1.8 m should be protected because they have been documented to be important staging habitat for sturgeon during summer (upriver) and fall (downriver) migrations (Wooley and Crateau, 1985). Also, subsurface limestone rock habitat with extensive vertical surface area should be protected because it provides substrate to which sturgeon eggs can adhere (Wooley and Crateau, 1985).

Artificial spawning grounds constructed of gravel have proven effective in prompting sturgeon to spawn. For example, artificial gravel beds have increased the extent of spawning habitat for lake sturgeon in the St. Lawrence River, Canada (LeHayle *et al.,* 1992, cited in Sulak *et al.,* unpublished), and for Russian sturgeon in the Volga and Kuban rivers (Khoroshko and Vlasenko, 1970, cited in Sulak *et al.,* unpublished). Gulf sturgeon in the Suwannee River selectively use calcium carbonate gravel with stones of mostly 2–10 cm in diameter, so if stones of this size were added to the Apalachicola River bottom, additional spawning habitat for sturgeon would be created (K. Sulak, USGS, personal communication). In addition to enhancing spawning success, such an artificial reef could also enhance the survival of developing sturgeon embryos (Sulak *et al.,* unpublished).

Under currently proposed federal water-development legislation, navigation would be removed as an authorized purpose of the JWLD. Although this would not automatically result in the dam's removal, it may make future removal more feasible should efforts to incorporate fish-passage modifications into the dam design and/or operation fail (D. Fruge, USFWS, personal communication).

The flow and velocity of the river need to be assessed, because inadequate water flows can cause the sturgeon eggs to clump together, which can promote infection that may kill the eggs. Too high a flow could prevent the eggs from adhering to the substrate and consequently cause them to be swept downstream. Also, high flows could require sturgeon to maintain above-normal physical activity.

Research is needed to assess the direct and indirect effects on all sturgeon life history stages of dredging the river and of disposing the dredged spoil, and solutions should be proposed to minimize the effects of these practices on sturgeon habitat. The NWFWMD is currently working with the USACOE to evaluate ways for reducing the harmful effects of disposing dredged materials in the river and on the floodplain; one such alternative is to dispose the dredged materials in specific sites. According to a permit issued by the USACOE (1999b), dredging is prohibited during the sturgeon spawning season to prevent the developing fish embryos from being conveyed downstream. To protect shellfish resources, the State of Florida requires that dredging and open-water disposal of spoil material in Apalachicola Bay occur from 1 December through 31 March; however, this period coincides with the time gulf sturgeon occupy and feed in the bay. Nutrients from agriculture and silviculture runoff, especially from upriver and adjacent states, should also be reduced.

The removal of logs from the river is also prohibited during the time of year sturgeon migrate upriver. According to FDEP Sovereignty Submerged Land Use Agreement—Attachment B, Prohibited Waterbodies for Removal of Pre-cut Timber, removal of precut timbers is prohibited in the Apalachicola River between Woodruff Lock and Interstate 10 during March, April, and May, which will help sturgeon migrate upriver towards to the dam.

Along the Apalachicola River, some areas are protected from development. In 1985, the NWFWMD acquired 14,370 hectares in the Apalachicola River drainage (NWFWMD, 1999); prohibition of development here will help protect gulf sturgeon habitat. The Apalachicola River Wildlife and Environment Area covers about 225 km^2 that stretch over swampy terrain from the town of Apalachicola upriver to Wewahitchka (Kirkland, 2000). Although much of this habitat is wetlands and is not directly used by sturgeon, its protection can help preserve adjacent sturgeon habitat. Acquiring 8,498 hectares in the upper Apalachicola River is a priority project because this area has several seepage streams that contain numerous endemic plant and animal species and has the highest species diversity in Florida (NWFWMD, 1998, 1999). Another important site, the Apalachicola National Estuarine Research Reserve (ANERR), covers 99,863 hectares and includes parts of the river and estuary, which are important habitats for gulf sturgeon (ANERR, 2000).

OCHLOCKONEE RIVER

CURRENT PHYSICAL CONDITION

The Ochlockonee River originates in Georgia, flows for 257 km (180 km of which are in Florida), and empties into Ochlockonee Bay (Seaman, 1988). The river is fed principally by rainwater runoff and receives little groundwater (NWFWMD, 1998). The Ochlockonee River is similar in topography and location to the Apalachicola River, and many of the rare and endangered species found in the Apalachicola River also occur in the Ochlockonee (NWFWMD, 1999). Because the Ochlockonee River is dependent on rainfall, the flow is highly variable throughout the year and from year to year (Purdum and Penson, 1998), and it is highly susceptible to pollution from land-use activities (NWFWMD, 1998, 1999).

Concerned about reported reductions in the sport fisheries of the upper Ochlockonee River, the Florida Legislature appropriated funds for the Florida Department of Environmental Regulation (FDER) to conduct a water-quality study of the river and determine whether man-made pollution was responsible for reduced numbers of sport fish (FDER, 1987). The FDER study showed that the Ochlockonee River receives discharges from point sources such as sewage treatment plants and industrial facilities and from nonpoint sources in urban and agricultural areas. When silt from dirt roads is carried into rivers by heavy rainfall, the rivers become shallower and so less suitable for sport fish (FDER, 1987).

The upper Ochlockonee River has high levels of nutrients, turbidity, and sediments from agricultural and silvicultural runoff, dirt-road maintenance, and out-of-state point sources (Purdum and Penson, 1998). In the middle reaches of the river, toxic levels of copper have been found. However, the lower river still has good water quality (Purdum and Penson, 1998). The Jackson Bluff Dam, which forms Lake Talquin (Wolfe *et al.*, 1988), leaves only 75 km of riverine habitat available to gulf sturgeon, and this stretch might not contain suitable substrate for spawning.

GULF STURGEON OCCURRENCES
IN THE OCHLOCKONEE RIVER

Multiple sightings of gulf sturgeon have been made at the base of the Jackson Bluff Dam (Reynolds, 1993). Near the mouth of Womack Creek, four gulf sturgeon weighing 2–4 kg were collected in June 1991, and six weighing 7.7–58.2 kg were collected in August and September 1993 (USFWS and GSMFC, 1995). Acting on the Gulf Sturgeon Recovery/Management Plan's recommendation to survey the Ochlockonee River for the presence of gulf sturgeon (USFWS and GSMFC, 1995), biologists surveyed the river near Curtis Mill and Woods Lake and captured and tagged six gulf sturgeon weighing 2.6–22 kg (F. Parauka, USFWS, personal communication).

IMPROVEMENTS TO ENHANCE HABITAT

The levels of pollutants released into the Ochlockonee River from agriculture and silviculture should be reduced, and roads should be paved to reduce dirt runoff. The improvement of the health of the Ochlockonee River is directly dependent upon a greater supply of good-quality water from as many parts of the river's watershed as possible (NWFWMD, 1998). Public ownership of erodible lands bordering this fast-flowing river will help reduce the likelihood of water-quality degradation, and to this end, the NWFWMD is trying to acquire 2,023 hectares in this subbasin (NWFWMD, 1999). The potential for fish passage around the dam should also be explored to increase upriver sturgeon habitat.

Suwannee System
(Appendix Figure A6)

SUWANNEE SOUND

CURRENT PHYSICAL CONDITION

Despite the fact that Suwannee Sound is one of the largest estuarine ecosystems between Tampa Bay and Apalachicola Bay on Florida's west coast and is a major feature of the Florida Big Bend coast (Mattson and Rowan, 1989), few recent studies have been conducted of the sound. The Big Bend coast stretches from Apalachee Bay in the north to Anclote Key in the south and consists of a broad (150 km wide), shallow coastal shelf (Mattson, 2000). The seagrass ecosystem along the

Big Bend coast is the second largest in the eastern Gulf of Mexico, encompassing an estimated 3,000 km^2 (Iverson and Bittaker, 1986, cited in Mattson, 2000). The sound is a complex of diverse natural communities and forms a major nursery for commercially important fish and invertebrates (Raulston *et al.*, 1998). Suwannee Sound supports large populations of benthic organisms (Mason, 1991), particularly polychaetes (Wolfe and Wolfe, 1985), which are prey for gulf sturgeon. The greatest threat to the Suwannee Sound is water-quality degradation from agriculture, silviculture, and urban runoff (Hornsby and Raulston, 2000).

GULF STURGEON OCCURRENCES IN THE LOWER SUWANNEE RIVER AND ESTUARY

Young sturgeon, those that weigh 0.3–2.4 kg, remain close to the river mouth and estuary during the winter and spring (Clugston *et al.*, 1995). According to studies by Sulak and Clugston (1998), estuarine-phase juvenile sturgeon 344.4–1003.8 mm in total length were common in winter gill-net samples (November through February) collected at the mouth of the Suwannee River. However, in the same studies, juvenile sturgeon 457.2 mm and smaller were rare in the estuary except during early February, which suggests that age-0 juvenile sturgeon do not migrate into the estuary in late October through early November along with the larger, sexually mature sturgeon (Sulak and Clugston, 1998).

Large immigrating gulf sturgeon feed in the sound or in the lower reaches of East and West passes on nearshore coastal-shelf organisms such as lancelets, brachiopods, pelagic shrimp, mollusks, starfish, and sea cucumbers (Mason and Clugston, 1993). Sturgeon collected 5 km offshore of West Pass had remains of both marine and estuarine organisms in their stomachs—including cumaceans, isopods, lancelets, polychaetes, and oligochaetes (Mason and Clugston, 1993)—which suggests sturgeon migrate out of Suwannee Sound into the Gulf of Mexico. Current sturgeon lavage stomach studies, conducted by D. Murie (University of Florida, Gainesville, personal communication), indicate that adult gulf sturgeon in Suwannee Sound principally eat brachiopods (Appendices B, C).

SUWANNEE RIVER

CURRENT PHYSICAL CONDITION

The Suwannee River, originating in the Okefenokee Swamp in southern Georgia, has 333 of its 394 km in Florida (Seaman, 1988) and has the second-largest volume of water flow in Florida (after the Apalachicola River) (Mattson *et al.*, 1995). The Suwannee River Basin is divided into three parts: upper, middle, and lower (Suwannee River Water Management District [SRWMD], 1999).

Water in the uppermost part of the Suwannee River basin comes mostly from land runoff, and water quality near the headwaters of the river is influenced by poorly drained, heavily vegetated sedimentary soils (Raulston *et al.*, 1998). The upper part of the river is poorly mineralized blackwater (Mattson, *et al.*, 1995), that is, it is deeply colored, acidic, low in dissolved inorganic compounds, and high in concentrations of organic material (Raulston *et al.*, 1998). The upper river is characterized by steep banks, swift currents, and numerous shoals (Huff, 1975).

Downriver, groundwater and numerous springs alter stream-water quality by lightening the water and increasing its pH to neutrality (Clugston *et al.*, 1995), both of which are characteristics of alkaline, hardwater, calcareous streams (Beck, 1965, cited in Seaman, 1988). The river widens and deepens in the middle. From mid-river to the mouth of the river, numerous springs feed the river, the river widens, and the vegetation consists of tidal marsh (Huff, 1975).

Despite its pristine appearance, the Suwannee River has been adversely affected by humans. Deadhead log removal and boat traffic have increased shoreline erosion (R. Mattson, SRWMD, personal communication). Levels of nutrients, bacteria, and turbidity have increased because of phosphate mining in the upper basin; croplands, poultry operations, dairies, and septic tanks in the middle reaches; and growing numbers of dairy farms and poultry plants in the lower basin (Raulston *et al.*, 1998).

The primary source of nitrate-nitrogen in the river is agriculture; nonpoint sources flow into groundwater and enter the surface-water system via springs (Hornsby and Mattson, 1997). Results from a three-day study on the lower 35 km of the Suwannee River showed that nitrate concentrations (loads) almost doubled from 0.46 to 0.83 mg/l. During the study, only 11% of the increase in nitrate load occurred in the upper 17 km of the Suwannee River; the remaining 89% occurred in the lower 35 km of the river. The difference in nitrate loadings between the two sites is a result of the magnitude of the spring discharge in the upper and lower river segments, the size and location of the spring basins, and the groundwater hydrology (Pittman *et al.*, 1995).

By designating the Suwannee River as an "Outstanding Florida Water," the State of Florida Environmental Regulation Commission has offered the river protection from major point-source discharges (Mattson and Rowan, 1989). According to F.S. 430.061 (27), "Outstanding Florida Waters" are those worthy of special protection because of their natural attributes. This statute provides maximum protection to these bodies of water—they cannot be changed.

Another protection to the Suwannee River is the prevention of deadhead log removal. According to the FDEP Sovereignty Submerged Land Use Agreement—Attachment B, Prohibited Waterbodies for Removal of Pre-cut Timber, The Lower Suwannee River National Refuge and the Suwannee River within state park boundaries are protected from deadhead log removal throughout the year. The Suwannee River from the Interstate 10 bridge north to the Florida Sheriff's Boys Ranch, inclusive of Section 4 Township 1 South Range 13 East, is protected from deadhead log removal during March, April, and May, the time of year when sturgeon migrate upriver to spawn.

Also, at least one-third of the Suwannee River basin land is under public ownership in the form of state parks (Ichetucknee River, Fanning Springs, Suwannee River), federal lands (Lower Suwannee National Wildlife Refuge), and forestry lands (R. Mattson, SRWMD, personal communication). These protections help to safeguard habitat from further destruction and thus preserve it for sturgeon habitat.

GULF STURGEON OCCURRENCES IN THE SUWANNEE RIVER

A sturgeon gillnet fishery, employing about 30 fishers, started in the Suwannee River in 1896. Records indicate that the primary motivation for the fishery was sturgeon meat, not caviar (Huff, 1975). The Suwannee River supported a limited commercial fishery for gulf sturgeon from 1899 until 1984, when the State of Florida prohibited harvest and possession of sturgeon (Wooley and Crateau, 1985).

Gulf sturgeon investigations have been conducted on the Suwannee River since 1986 by the Caribbean Conservation Corps; University of Florida, Gainesville; USFWS; and USGS. More than 5,000 gulf sturgeon have been collected and tagged in the Suwannee River system (Sulak and Clugston, 1999). Population estimates of gulf sturgeon greater than 61 cm total length and older than age two in the Suwannee River range from 3,152 (Chapman *et al.,* 1997) to 7,650 (Sulak and Clugston, 1999).

All sizes and ages of gulf sturgeon have been collected throughout the river. However, gulf sturgeon make limited use of the uppermost Suwannee River (above river km 237) and the three major Suwannee tributaries: the Withlacoochee, Alapaha, and Santa Fe rivers (Sulak and Clugston, 1999). The lower river is an important staging area for seasonal emigration and immigration of adult and subadult gulf sturgeon. After the spring emigration and spawning interval, adults and subadults spend summer through fall in the middle and lower reaches of the river. Once in the river, sturgeon usually hover within 152 m of one of the Suwannee River's 52 springs. Gulf sturgeon prefer deeper spots, usually located at river bends (Brandt, 1988). The many large constant-temperature springs throughout the Suwannee River have assuredly contributed to the success of gulf sturgeon by providing thermal refugia during summer (Foster and Clugston, 1997). Upstream water quality and groundwater flows should be maintained so that this sturgeon habitat will be protected.

The Suwannee River supports the largest, healthiest, most viably functioning population of gulf sturgeon in Florida (Clugston *et al.,* 1995; Carr *et al.,* 1996; Raulston *et al.,* 1998). The ultimate survival of a sustainable gulf sturgeon population in Florida may depend upon the successful periodic reproduction of the Suwannee River sturgeon population, because this river is the only major unimpounded, undiverted, relatively unpolluted river along the coast of the northwestern Gulf of Mexico (Randall and Sulak, 1999). Although no more commercial harvest of gulf sturgeon is allowed, biologists studying various life-history aspects of sturgeon and sturgeon populations capture both sexually mature and immature male and female sturgeon annually as they migrate upriver. During the spring of 2001, the University of Florida researchers biopsied sturgeon to determine their state of sexual maturity. Sonic transmitters were implanted in both immature and mature male and female sturgeon, and the fish are being tracked to study the effects, if any, of removing eggs and sperm from mature fish (Appendix C). Another source of sturgeon mortality is pleasure boating: in midsummer, when sturgeon are not feeding, adult and subadult gulf sturgeon occupy a small number of holding areas, and during this nonfeeding period, sturgeon repeatedly jump in these areas; their repeated jumping in these small areas makes them vulnerable to boats passing through (Sulak *et al.,* unpublished). Boat speeds should be limited within the main areas that sturgeon inhabit during summer (Sulak *et al.,* unpublished).

IMPROVEMENTS TO ENHANCE HABITAT

Florida Administrative Code 68B-31.017 closes 191,300 hectares of the Big Bend area to shrimp trawling year-round, which probably helps to protect gulf sturgeon populations. Several nonprofit, state, and federal agencies have been working to protect the Suwannee River and its adjacent habitats. In the Suwannee River region, the FDEP, instead of the SRWMD, is the primary permitting regulatory agency, although the SRWMD is also actively involved in river-management issues, including setting out the following goals in the SRWMD Surface Water Improvement Management (SWIM) plan (SRWMD, 1991):

- to identify, analyze, and more completely define the point and nonpoint sources of pollution

and their effects within the basin and to determine ways of reducing pollution levels through improving water-quality standards, increasing enforcement, and revising rules;
- to continue the ongoing program of monitoring changes in water quality, natural biological resources, and vegetation cover; and
- to provide technical assistance to local governments in land-use planning, regulation, and management to ensure the protection of surface-water quality and habitat.

The USFWS initiated studies in 1987 to determine growth rates, food habits, movement, habitat preferences, and seasonal abundance of gulf sturgeon in the Suwannee River and its estuary (Clugston *et al.,* 1995). The Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995) recommended the following studies on the Suwannee River:
- develop databases on physical, chemical, and biological characteristics for use with Geographical Information Systems;
- assess water quality; and
- assess the effects of human-induced disturbances on the benthic communities.

Save Our Suwannee, an environmental citizens group formed to protect the river, helps to educate the public on issues affecting the Suwannee River Basin. Some of the issues they are addressing include reducing the levels of nitrates entering the river from dairy farms and other agricultural concerns and helping both to identify additional point-source pollutants from nearby cement plants and other industries and to prevent these pollutants from entering the river (J. Clugston, Save Our Suwannee, personal communication).

The SRWMD is working to purchase more private shoreline land along the Suwannee River to protect riverine habitat, and it is making existing permits more restrictive to prevent additional habitat destruction in the river. In 1994, the SRWMD and the USGS began a long-term cooperative study with the goals of determining the minimum and maximum flows and water levels needed to manage the surface water and groundwater resources of the Suwannee River District and of maintaining or improving the various ecosystems (Raulston *et al.,* 1998). Currently, the SRWMD manages 6,532, 6,095, and 6,635 hectares in the upper, middle, and lower Suwannee River, respectively (SRWMD, 1999). The district would like to acquire an additional 13,077, 7,021, and 5,267 hectares, respectively, in these basins. However, under the current Florida Forever Program, the SRWMD, like the NWFWMD, will receive only 7.5% (compared to 10% under the previous Preservation 2000 Program) of the total 35% of total funds allocated to acquire lands (NWFWMD, 2000).

The Suwannee River Basin Nutrient Management Group—a coalition of state, federal, and regional agencies, local government, and private industry—is working to reduce nitrate levels in surface water and groundwater within the Suwannee River Basin. The principal goals of the management group are to determine the source of nutrients and then to encourage local land-users to take part in voluntary, incentive-based programs that will minimize future nutrient-loading. Through an education and outreach program, the group plans to increase public awareness of the issues affecting the Suwannee River Basin and encourage citizen and community groups to work together in finding solutions (SRWMD, 2000).

Tampa Bay System
(Appendix Figure A7)

BAYS

CURRENT PHYSICAL CONDITION

Tampa Bay, Florida's largest open-water estuary, spans almost 1,036 km^2 and receives drainage from a watershed that at 5,698 km^2 is more than five times the bay's size (Zarbock *et al.,* 1994, cited in TBNEP, 1996). The Tampa Bay National Estuary Program (TBNEP) was established in 1991 to assist the Tampa Bay community in developing a comprehensive plan to restore and protect Tampa Bay (TBNEP, 1996). The Tampa Bay system comprises "Old" Tampa Bay, "Middle" Tampa Bay, "Lower" Tampa Bay, Hillsborough Bay, Boca Ciega Bay, and Terra Ceia Bay; the main sources of fresh water are the Manatee River, Little Manatee River, Hillsborough River, and Alafia River. Old Tampa Bay has a surface area of approximately 200 km^2 and a volume of 548 million m^3 (Zarbock *et al.,* 1995). Of the three main sections of the bay (Old, Middle, and Lower), Old Tampa Bay has the highest volume of tidal flows, and it has the highest nitrate and phosphate inputs because its shorelines are the most completely urbanized (Zarbock *et al.,* 1995). Middle Tampa Bay has a surface area of approximately 310 km^2 and a volume of 1,166 million m^3 (TBNEP, 1999). Lower Tampa Bay has a surface area of approximately 247 km^2 and a volume of 1,242 million m^3 (TBNEP, 1999). Lower Tampa Bay is the least affected by urban growth of the three main bay segments and has the best water quality (Zarbock *et al.,* 1995).

Hillsborough Bay has an area of 105 km^2 and a volume of 306 million m^3 (Zarbock *et al.,* 1995). This bay contributes the largest volume of freshwater inflow (30%) into Tampa Bay (TBNEP, 1999), even though it has the smallest total volume of all the six segments (Zarbock *et al.,* 1995)—it is the only bay segment with significant volumes of freshwater inflow originating from point sources (Zarbock *et al.,* 1995), and the bay also receives the greatest amount of groundwater from springs located in the Hillsborough River (Zarbock *et al.,* 1996). Also, in Hillsborough Bay, low salinity plays a dominant role in the abundance and diversity of benthic invertebrates, which provide food for bottom-dwelling fishes—the invertebrates decrease in numbers and species diversity as the salinity decreases (TBNEP, 1999).

Hillsborough Bay is the most industrialized portion of Tampa Bay and has the highest levels of nitrogen and phosphorus and the greatest inflow of nonpoint-source and point-source (domestic and industrial) pollutants of the six bay segments (Zarbock *et al.,* 1996; TBNEP, 1999). According to a study of chemical contaminants in fish from throughout Tampa Bay, concentrations of PCBs, DDTs, and alpha-chlordane in the liver and fluorescent compounds in bile were highest in fish from sites in or near Hillsborough Bay (McCain *et al.,* 1996).

Boca Ciega Bay has a surface area of 93 km^2, drains an area of 238 km^2, and has 6% of Tampa Bay's total freshwater inflow, the second-smallest percentage of freshwater inflow of the six Tampa Bay segments (TBNEP, 1999). Terra Ceia Bay has a surface area of 21 km^2, drains an area of 36 km^2, and has the smallest freshwater inflow (1%) as well as the lowest nitrogen and phosphorus inputs of the six Tampa Bay segments (TBNEP, 1999).

An assessment by the TBNEP (TBNEP, 1999) shows that ecosystems within Tampa Bay have been altered by sedimentation and eutrophication. Tampa Bay contains sediments that are contaminated with heavy metals, organic compounds, and other pollutants, and dredging and filling operations in the bay have destroyed submerged aquatic habitat (Wheeler *et al.,* 1998). However, according to the TBNEP Baywide Environmental Monitoring Report, the levels of dissolved oxygen, total phosphorus, and chlorophyll were better during 1993–1998 than they were during the late 1970s and early 1980s (TBNEP, 1999).

Point-source pollutants consist of domestic, industrial, and spring discharges. These discharges can enter the bay through streams, creeks, and rivers. Nonpoint sources such as ground applications of pesticides, fertilizers, or herbicides are more difficult to measure and can runoff by discharging to a settling pond or to an irrigation system and then to the bay (TBNEP, 1999).

GULF STURGEON OCCURRENCES IN TAMPA BAY

The first significant commercial gulf sturgeon fishery on the Florida gulf coast opened in Tampa Bay in 1886 and operated effectively for 3 years until annual sturgeon catches dropped from approximately 2,000 to 7 sturgeon (U.S. Commission of Fish and Fisheries, 1902, cited in Wooley and Crateau, 1985). However, sturgeon have been caught sporadically in Tampa Bay since 1890. A gulf sturgeon was collected in December 1987 in Boca Ciega Bay (FMRI fish collections number FSBC 18060). A gulf sturgeon weighing 25.8 kg was collected in December 1987 near Pinellas Point (FMRI fish collection records, no collection number). According to the summary of public responses compiled by Reynolds (1993), sturgeon were caught by gillnetters in Tampa Bay in 1987, and a commercial gillnetter incidentally caught and released a 56.4-cm sturgeon in the gulf one mile west of Redington Beach (north of St. Petersburg Beach) in December 1992. A gulf sturgeon weighing 30 kg and measuring 1.5 m was found at Port Manatee in January 2001. However, no directed research has been done on sturgeon occurrence in Tampa Bay and its tributary rivers (A. Huff, FMRI, personal communication).

IMPROVEMENTS TO ENHANCE HABITAT

Tampa Bay is the focal point of the SWFWMD's program activities because the bay has been designated as the prime water body for habitat preservation and restoration (Wheeler *et al.,* 1998). TBNEP research has shown that to maintain a healthy estuarine ecosystem, we must preserve adequate freshwater flows to the bay and better understand the flushing and circulation patterns within the bay. Pollutants play a large role in Tampa Bay's water quality. Therefore, controlling and reducing the amount of nonpoint-source and point-source pollutants (such as nitrogen, toxic chemicals, suspended solids, and sediments) discharged to the rivers flowing into Tampa Bay will be essential to the recovery of all components of the seagrass ecosystem, including invertebrates and fish.

The SWFWMD has many plans for acquiring land in the Tampa Bay watershed. In acquiring additional lands, SWFWMD can help protect habitat that will be important to sturgeon if they can be restored to this ecosystem.

RIVERS OF TAMPA BAY

Four rivers flow into Tampa Bay: the Hillsborough, the Alafia, the Little Manatee, and the Manatee. Freshwater input to Tampa Bay is 63 m^3 per second, or about 2 billion m^3 annually, and flow from the four major rivers contributes about 70%–85% of this input. The two largest river basins are the Hillsborough River Basin, which encompasses 26% of the entire Tampa Bay watershed, and the Alafia River Basin, which encompasses 14% of the entire watershed. Together, the Hillsborough and Alafia rivers contribute 44% of the total freshwater inflow to Tampa Bay (TBNEP, 1999).

HILLSBOROUGH RIVER

The Hillsborough River is 88 km long (Seaman, 1988), and the Hillsborough Watershed encompasses urban, suburban, commercial, and agricultural lands (SWFWMD, 2000). Although most of the river systems in the northern Tampa Bay area are fed almost totally by land runoff, the Hillsborough River receives significant contributions from the Upper Floridan Aquifer through many springs in its bed and at the base of its banks (SWFWMD, 1996). The Crystal Springs Recreational Preserve, a 214-hectare, privately owned area, contains the largest source of water to the Hillsborough River.

The Hillsborough River is dammed in downtown Tampa, 16 km above its mouth, to form the Hillsborough River Reservoir. The original impoundment dates back to the late 1800s (Estevez *et al.,* 1991). The dam on the Hillsborough River releases almost no water downstream during peak periods of the dry season; annually, the river retains about 35% of its up-river flows for human uses such as drinking, irrigation, and industry (TBNEP, 1996). Major water-quality problems in the Hillsborough River Reservoir have been high nutrient and heavy metal concentrations, which have resulted in low dissolved oxygen levels (Water and Air Research Inc. and SDI Environmental Services, Inc., 1995).

Extensive areas in the upper and lower Hillsborough River would be suitable habitat for gulf sturgeon. These sections of river contain shallow sandbars and flats, unvegetated sand bottoms, vegetated sand bottoms, sand over bedrock, uneven bottom, deep areas near bends in the river, deep holes, and areas of exposed bedrock. In the lower reach of the Hillsborough River (below the dam), about 24% of the shoreline habitat is classified as "natural" (Water and Air Research, Inc. and SDI Environmental Services, Inc., 1995); much of the upper river habitat is similar to the upriver habitat of the Suwannee River, which supports a large population of sturgeon. A pilot project in the Hillsborough River is in progress to determine whether the habitat is suitable for 48 1998-year-class gulf sturgeon. These sturgeon were implanted with sonic tags, and 24 were released upstream and 24 were released downstream of the dam; they are being monitored and tracked on a biweekly basis (Appendix C).

Hillsborough River State Park, one of Florida's oldest parks, consists of 1,212 hectares. The Hillsborough River flows through the park over outcroppings of Suwannee limestone; the Suwannee limestone outcroppings in this park are the southernmost of this formation in Florida (Hillsborough River Greenways Task Force, 1995). This limestone helps to neutralize the water pH and provides suitable spawning habitat for sturgeon. An additional five parks managed as part of the Hillsborough County Wilderness Park system (Hillsborough River Greenways Task Force, 1995) contain protected habitat that is suitable for gulf sturgeon. The SWFWMD has planned nine land-acquisition projects for the Hillsborough River watershed, some targeting the purchase of lands along some of the river's principal tributaries and others targeting the purchase of water resource areas in the more undeveloped sections of the river basin (SWFWMD, 1999).

ALAFIA RIVER

The Alafia River is 80.5 km long[4] and drains a watershed of 1,191 km^2, which has been altered by urban and suburban development, agriculture, and phosphate mining (SWFWMD, 1999). Three land-acquisition projects are planned in this watershed. The largest of these projects involves the purchase of a buffer corridor of wetlands that is connected with the Little Manatee River to the south.

LITTLE MANATEE RIVER

The Little Manatee River is 64 km long and has a watershed of approximately 575 km^2 (SWFWMD, 1999). Because development has been less intense along the Little Manatee River than it has been in the other rivers that flow into Tampa Bay (SWFWMD, 1999), this river is in the best hydrobiological condition of all the rivers that flow into Tampa Bay (Estevez *et al.,* 1991). However, the Little Manatee River also has a dam that restricts fish movement upriver and releases almost no water downstream during peak periods of the dry season, and development in the downstream portion of the river is increasing. A proposed SWFWMD project on the Little Manatee River will protect riverine floodplain wetlands and adjacent uplands and will provide a continuous greenway link to the Alafia River (SWFWMD, 1999).

MANATEE RIVER

The Manatee River flows for a total distance of 97 km (including both freshwater and saltwater segments). The entire watershed encompasses 971 km^2 of mostly rural and agricultural lands. The first part of the Manatee River, approximately 21 km long, is estuarine and tidal. Eight km below the confluence of its two major tributaries, the North Fork and East Fork, the Manatee River is dammed to form Lake Manatee

[4]The main stem of the Alafia River is 32 km long, but if the North and South prongs are included, the river is 80.5 km long (S. Flannery, SWFWMD, personal communication).

(SWFWMD, 1999). Annually, the dam releases almost no water downstream during peak dry seasons and retains 29% of upriver flows for drinking, irrigation, and industrial uses (TBNEP, 1996). A dam is also located on the Braden River, which also feeds into the Manatee River. In addition to nonpoint-source-pollution input, the Manatee River also has a substantial industrial point-source loading of total suspended solids (TBNEP, 1999). Three land-acquisition projects within the Manatee River Watershed will protect water quality and wildlife habitats. One of these projects will form a continuous greenway between the Manatee and the Little Manatee rivers (SWFWMD, 1999).

CONCLUSION

The rivers that flow into Tampa Bay form important habitat for several species of fish and other wildlife (Hillsborough River Greenways Task Force, 1995) and could be important gulf sturgeon habitat. However, the habitat needs of gulf sturgeon should be assessed to determine whether habitat is present and is sufficient for all sturgeon life-history stages. Next, small-scale pilot projects need to be conducted. If the first pilot project on the Hillsborough River proves successful, additional life-history stages of gulf sturgeon may be added to this ecosystem; pilot projects involving stocking gulf sturgeon in other rivers that feed Tampa Bay could be conducted in the future.

Charlotte Harbor System

(Appendix Figure A8)

CHARLOTTE HARBOR

CURRENT PHYSICAL CONDITION

The Charlotte Harbor estuarine system has a surface area of 699 km^2 and is connected to the Gulf of Mexico through the passes between barrier islands (McPherson *et al.,* 1996). After Tampa Bay, Charlotte Harbor is the second-largest open-water estuary in Florida. Charlotte Harbor and the contiguous coastal waters serve as a home, feeding ground, and nursery area for more than 270 species of fish.

Alterations to the aquifer and the introduction of excess fresh water have changed the hydrology in the Charlotte Harbor Basin. Charlotte Harbor also has the smallest acreage of well-drained soils of any of the estuarine basins in Florida. According to Post *et al.* (1999), the three principal problems that contribute the most to the degradation of the Charlotte Harbor system are (1) hydrologic alterations caused by adverse changes in the amount, location, and timing of freshwater flows (including natural river flows) and in the hydrology of the floodplain; (2) water-quality degradation, including but not limited to pollution from agricultural and urban runoff, from point-source discharges such as septic tanks, from deposition of airborne pollutants, and from tainted groundwater; and (3) fish and wildlife habitat loss caused by development (*e.g.,* alteration of natural shorelines by dock construction and boat traffic and by invasion of exotic species).

GULF STURGEON OCCURRENCES IN CHARLOTTE HARBOR

Gulf sturgeon have been sighted only seven times over a span of almost 40 years, which suggests that the number of gulf sturgeon using Charlotte Harbor may be small (G. Carmody, USFWS, personal communication). Most sightings of sturgeon in Charlotte Harbor have occurred during fall and winter. A gulf sturgeon weighing 25 kg was caught in a net in Port Charlotte in January 1960 (Fort Myers News Press, 1960; FMRI records FSBC 18077), and one measuring 98.7 cm fork length was captured in an otter trawl west of Barron Collier Bridge in February 1982 (T. Fraser, Environmental Quality Laboratory, Port Charlotte, personal communication). A gulf sturgeon weighing 3 kg was captured by a commercial net fisher on a sandbar near Boca Grande Pass near the mouth of Charlotte Harbor in January 1992 (R. Ruiz-Carus, FMRI, personal communication).

Wooley and Crateau (1985) suggested that gulf sturgeon may occasionally migrate southward and inhabit Charlotte Harbor during winter, and both documented and anecdotal information (FMRI sturgeon records; Reynolds, 1993; USFWS and GSMFC, 1995; P. Fricano, FDEP, personal communication; D. Model, National Wildlife Federation, personal communication) also indicate that gulf sturgeon were occasionally found in Charlotte Harbor during the winter months. However, collection records indicate that sturgeon also occur in Charlotte Harbor at times other than winter (August and October; Charlotte Harbor National Estuary Program records, 1960–1998). According to A. Huff (FMRI, personal communication), the prevalence of winter captures of gulf sturgeon was most likely the result of the use of gillnets in the mullet fishery.

PILOT HABITAT PROJECT

In 1999, Charlotte Harbor National Estuary Program, USFWS, and FWC developed a plan to introduce 10 sonic-tagged gulf sturgeon into Charlotte Harbor to document the distribution patterns and habitat use of gulf sturgeon in the fresh and marine waters of this ecosystem (G. Carmody, USFWS, personal communication). However, because habitat in the bay may be limited and because of a lack of funding and person-

Table 8. *Summary of information on gulf sturgeon.*

	Escam	Yellow	Black	Choctaw	Apalach	Ochlock	Suwan	Hillsbor
Research								
Good water quality?	N	Y	Y	Y	Y	Y	Y	Y
Population?	N	N	N	Y	Y	N	Y	N
Estimate				3,000	320		7,650	
Sturgeon collected/ research?	Y/Y	Y/Y	Y/N	Y/Y	Y/Y	Y/N	Y/Y	N/Y
Presence of suitable habitat								
Spawning habitat	Y	Y	?	Y	Y	Y	Y	Y
Other life stages	?	?	?	?	?	?	?	?
Barriers that restrict migration								
In Florida	N	N	N	N	Y	Y	N	Y
North of Florida	Y	N	N	Y	Y	N	N	N
Programs needed to increase habitat for Gulf sturgeon								
Reduce sediments	Y	Y	Y	Y	Y	Y	Y	Y
Reduce nutrients	Y	Y	Y	Y	Y	Y	Y	Y

KEY:
N = No; Y = Yes; Escam = Escambia; Yellow = Yellow; Black = Blackwater; Choctaw = Choctawhatchee;
Apalach = Apalachicola; Ochlock = Ochlockonee; Suwan = Suwannee; Hillsbor= Hillsborough.

nel commitment, the project was not executed. Plans may exist for pilot-scale gulf sturgeon projects in the Charlotte Harbor watershed in the future. Before sturgeon populations can be restored in the Charlotte Harbor watershed, the habitat they need to survive must be restored and protected.

Summary of Florida West Coast Estuaries and Rivers

The estuaries from Pensacola Bay to Suwannee Sound can and do support gulf sturgeon populations during part of the year, and many of the rivers that feed these estuaries would support reintroduced gulf sturgeon. Sedimentation and nutrient loading are the primary problems affecting these ecosystems. Representatives from county, local, and state governments are discussing ways to deal with problems that stem from high loads of sediments and nutrients in the Florida west coast bays. Gulf sturgeon may repopulate Florida's west coast estuaries and rivers on their own if habitat improvements are implemented. However, for sturgeon populations to be restored through natural production in perturbed rivers, resource managers must be knowledgeable of the abiotic and biotic factors that influence sturgeon spawning and the factors that can harm or kill embryonic, larval, and juvenile sturgeon (M. Parsley, USGS, Columbia River Research Laboratory, personal communication). Therefore, it is essential to determine the minimal as well as the optimal requirements for each sturgeon life-history stage, so that sturgeon can successfully proceed from one stage to the next. A summary of information on gulf sturgeon in the primary rivers of western Florida that currently have or historically had populations of gulf sturgeon and a list of the studies that most need to be conducted to ensure the continued presence or renewal of populations of gulf sturgeon in those systems are presented in Table 8.

Stock Enhancement

Humans, through such actions as constructing dams and other impoundments on rivers (Burke and Ramsey, 1985; Hurley *et al.,* 1987; USFWS, 1993), continue to alter riverine habitat in ways that are not conducive to sturgeon survival. Restoration efforts that do not address habitat degradation have generally failed to restore sturgeon populations to historical levels of productivity (Beamesderfer and Farr, 1997) because systemwide habitat protection and enhancement measures have been extremely difficult to implement and, in some cases, have actually harmed natural sturgeon populations. If sturgeon populations become too small, they cannot sustain themselves because of both genetic and nongenetic factors. Thus, some existing sturgeon populations may need to be enhanced by stocking, and many fishery managers have had to rely on culturing and stocking to enhance sturgeon populations. These measures can effectively maintain populations and provide fishery benefits where habitat degradation is not severe or while habitat improvements are being made.

The recovery process for the Kootenai River populations of white sturgeon (*Acipenser transmontanus*) in Idaho, Montana, and British Columbia incorporates both conservation aquaculture and ecosystem restoration simultaneously (Anders, 1998). Conservation aquaculture—growing fish for the purpose of recovering and restoring endangered fish populations—involves developing a breeding strategy to preserve the population's remaining genetic variability. Conservation aquaculture, unlike traditional aquaculture, involves working adaptively with the local gene pool to allow sufficient migration of genes to allow allelic representation through careful selective breeding programs (Anders, 1998). At the same time as this breeding strategy is being developed, a plan for restoring the river conditions to those conducive to natural spawning, larval survival, and natural recruitment should be initiated. However, the process of restoring sturgeon populations by stock enhancement requires extensive knowledge of the life-history and reproductive biology of sturgeon and knowledge of river productivity and fish-community dynamics, all of which can be acquired only by extensive research.

Hatchery-based stocking (reintroduction or supplementation) of sturgeon might accelerate the rate of recovery of wild stocks because some populations of sturgeon might not be able to recover naturally on their own. Transplanting sturgeon from one population to another or from one section of a river to another should also be considered (T. Rien and J. North, Oregon Department of Fish and Wildlife, personal communications). Conservation aquaculture is another method that could possibly be used to restore sturgeon populations (P. Anders, University of Idaho, Aquaculture Research Institute, S. Ireland and J. Siple, Kootenai Tribe of Idaho Fisheries Department, personal communications). However, researchers differ on their views of artificially propagating sturgeon to restore extirpated populations or depleted wild populations: some feel it can be a tool for recovery, whereas other experts feel it would threaten the long-term survival of the species (Shortnose Sturgeon Recovery Team, 1998; ASMFC, 1992).

Considerations

Restoring sturgeon populations through stocking should be attempted only after sufficient habitat conditions for all sturgeon life-history stages are present. Reintroductions of sturgeon should be conducted only when funds are available to monitor the success of the restoration, and a suitable wild sturgeon donor stock must be available to supply the broodfish.

GENETIC DIVERSITY

It is extremely important to maintain genetic diversity in natural sturgeon populations. Tringali and Leber (1999) described three types of hazards that lower the genetic diversity in native populations: (1) hazards that result from the transfer of exogenous genes by hatchery-reared sturgeon into populations of wild sturgeon (*e.g.,* outbreeding depression due to breakdown of local adaptations or disruption of coadapted genomes); (2) hazards that stem from genetic changes in the hatchery population regardless of the source of broodstock (*e.g.,* low diversity, artificial selection, and domestication); and (3) hazards related to the genetic swamping of natural populations by successful stock enhancement (these hazards may occur even when those of 1 and 2 have been mitigated).

Considerable genetic risks also exist for the hatchery-reared fish. According to Campton (1995), at least three factors can lead to genetic changes in a cultured population: (1) intentional or artificial selection for a desired trait (such as growth rate or adult body size); (2) selection resulting from nonrandom sampling of broodstock; and (3) unintentional or natural selection for certain morphological or behavioral characteristics brought about by the hatchery environment.

Because large populations of sturgeon are usually genetically diverse, the individuals in these groups are more likely to adapt to changes in habitat conditions than individuals in small, less genetically diverse populations are. Small populations are more vulnerable to the deleterious effects of genetic drift; inbreeding and outbreeding depression, including reduced fitness of individuals and populations; and diminished resistance to disease. Nongenetic risks can also adversely affect small populations (Anders, 1998). For intermediate-sized populations, genetic risks are more difficult to quantify (Waldman and Wirgin, 1998). Therefore, when fish are being cultured for restoration purposes, a breeding population of sufficient size must be maintained to ensure the genetic integrity of the local recipient stock.

Although enhancement stocking may increase adult abundance in the short term, it may alter the genetic basis for local adaptations of the wild populations, possibly resulting in a long-term decline in the fitness and the abundance of the population (Waples, 1991; Fleming, 1994; both cited in Kynard, 1997). Populations of hatchery fish may also be deficient in overall genetic variability, and they could ultimately reduce the genetic variability of the wild population into which they are released (Tringali and Bert, 1998). The chances of the genetic makeup of hatchery-reared sturgeon being altered are reduced if fish are released early in their life cycle (*e.g.,* in the case of salmon, as fry or parr, rather than as smolts). But if sturgeon are released from the hatchery at too early a developmental stage, they may not survive in the wild (Waples, 1999).

Taking and fertilizing large numbers of eggs of wild sturgeon broodstock (*i.e.,* source spawning) for stock-enhancement purposes could cause a decline in the number of eggs released in the wild (K. Sulak, USGS, personal communication). In addition, removing eggs and sperm from wild sturgeon could reduce the genetic diversity of the wild population. Although the founder effect in the hatchery population will be minimized by removing a large number of eggs from the wild population, a larger portion of the wild population will be cultured in the hatchery. Hatchery fish released into the wild could affect the remaining natural population demographically or genetically (Waples, 1999), but in some cases, the loss of genetic diversity in the wild population can be minimized or even reversed by following genetically efficient stocking protocols (Ryman *et al.,* 1995).

USE OF WILD BROODSTOCK

Whenever possible, wild sturgeon broodstock used for culture purposes should be from the same river in which stocking will occur. When native sturgeon broodstock no longer exist, or are in such low abundance as to hinder collection, the source of broodfish should be taken from the regional genetic grouping to which the original population belonged, or broodfish should be taken from adjacent, hydrologically similar river systems (St. Pierre, 1996). It is also important to use a sufficient number of sturgeon broodfish to prevent inbreeding (Wirgin *et al.,* 1997) and to adequately represent the inherent variation in the stock (St. Pierre, 1996). Sturgeon broodstock should be collected at times of year and in numbers that do not unduly stress the native population. St. Pierre (1996) also recommended that wild broodfish should be spawned only once, and after spawning, they should be externally marked and returned to their river of origin. Some biologists believe that gulf sturgeon populations are recovering through natural reproduction and that the removal of females in spawning condition from one population to supplement another population could adversely affect continued recovery of the donor population. Any removal of sturgeon from a particular system may affect natural reproduction in that system.

IMPRINTING AND STRAYING

In what is called "homing behavior," fish adapt to their native populations and to the habitat occupied by that population (Leggett, 1977). Such behavior is thought to result in reproductive isolation and fish stocks that are unique in behavior, energetics, and reproductive characteristics (Leggett, 1977). Tagging studies suggest that gulf sturgeon show a high degree of river fidelity. From 1981 to 1993, 4,100 gulf sturgeon were tagged in the Apalachicola and Suwannee rivers; 860 (21%) were recaptured in the river of initial collection and 8 subadults (0.002%) moved into other rivers (USFWS and GSMFC, 1995; Carr *et al.,* 1996; Foster and Clugston, 1997). This high degree of natal stream fidelity has been proposed as the reason for the existing genetic structure of gulf sturgeon populations (Stabile *et al.,* 1996).

Genetic studies using mitochondrial DNA to identify stocks of sturgeon (Ong *et al.*, 1996; Stabile *et al.*, 1996) and multilocus microsatellite DNA studies (T. King *et al.,* unpublished data[5]) show that the gulf sturgeon's homing fidelity to particular regions is remarkably high, and in many cases, sturgeon return to specific rivers within a region. Stabile *et al.* (1996) analyzed gulf sturgeon populations from eight river drainages along the Gulf of Mexico for differences in genetic make-up. He noted significant genetic differences between gulf sturgeon stocks and suggested that sturgeon display region-specific affinities and may exhibit river-specific fidelity. Stabile *et al.* (1996) was able to differentiate five regional gulf sturgeon stocks (listed here from west to east): (1) Lake Pontchartrain and the Pearl River, (2) the Pascagoula River, (3) the Escambia and Yellow rivers, (4) the Choctawhatchee River, and (5) the Apalachicola, Ochlockonee, and Suwannee rivers. The sturgeon returning to rivers in the eastern gulf (the Suwannee, Ochlockonee, and Apalachicola rivers) do not have as high a degree of homing to individual rivers as do sturgeon from more westerly rivers (Stabile *et al.,* 1996). Straying of gulf sturgeon between the Apalachicola and

[5]King, T., B. A. Lubinski, and I. Wirgin. (Unpublished.) High resolution of gulf sturgeon population structure with multilocus microsatellite DNA genotypes. U.S. Geological Survey, Leetown Science Center, Aquatic Ecology Lab, Kearneysville, West Virginia.

Suwannee systems could have caused their high degree of genetic similarity (Stabile *et al.,* 1996).

Imprinting is an important concern if the stocking of cultured fish is to be successful in enhancing or restoring the stock in a particular river. Imprinting of gulf sturgeon likely occurs at a very early age, as it does in other anadromous and catadromous species, but the age of imprinting has not yet been determined. Stocked shortnose sturgeon (*Acipenser brevirostrum*) tend to stray if they are stocked at ages greater than one year, but these data are preliminary (M. Collins, South Carolina Department of Natural Resources, personal communication). Young fish (*i.e.,* less than six months) that were reared in a hatchery might be able to imprint to the river in which they were transplanted, but fish older than one year might be imprinted to the hatchery water before their release to the transplant river. Consequently, if hatchery-reared sturgeon have already been imprinted with water from the hatchery, by the time they are released, the sturgeon may attempt to return to the aquaculture facility when its time to spawn rather than to the river in which they were transplanted, even if the aquaculture facility is far from the river into which they are released.

Therefore, in order for hatchery fish to imprint on the river into which they are stocked, they must either be stocked prior to the age of imprinting, or the hatchery/culture facility must use water from the river into which the fish will be stocked. Stocking prior to imprinting reduces the probability of survival of the stocked fish and also interferes with evaluation of the success of the stocking program because marking very young fish for future identification is difficult unless coded wire tags are used. Using water from the river to be stocked is unwise because raw surface water contains disease, parasites, and larval predators that can interfere with survival in the hatchery. Treatment of the water prior to hatchery use could alter its utility for imprinting.

Overview of Potential Genetic Concerns

A challenge to the hatchery production of sturgeon is the need to acquire sufficient broodstock to prevent inbreeding (Nelson and Soule, 1987, cited in Wirgin *et al.,* 1997). If cultured fish are reared from a few wild fish, their degree of genetic diversity could be lowered, and they might not be as likely to survive if reintroduced into a wild population. Stabile *et al.* (1996) recommend that hatchery fish released to the wild should have the clear genetic differentiation of the gulf sturgeon population in the area where the release is to occur—that is, do not introduce a new genetic strain to a native population. T. King (USGS, personal communication) also endorses this recommendation. Because the Suwannee River gulf sturgeon population is genetically identical to remnant populations in the Ochlockonee and Apalachicola rivers, exchange between these rivers may be allowed (Sulak, 1998). However, in addition to the genetic matters, local disease resistance and behavior adaptation may be important considerations. Because native gulf sturgeon in the Suwannee River have a low genetic diversity, the precise genetic structure of this population needs to be determined. However, increasing genetic diversity in a low-diversity population may not necessarily be the goal of choice because the population could have evolved with a low genetic diversity for a reason that we do not understand. Hence, it could be more beneficial to allow natural populations of sturgeon to recover rather than to try to enhance populations by stocking, because stocking from a distant river could increase genetic diversity of the resident population but reduce within-population genetic integrity via outbreeding (Tringali and Leber, 1999).

Research Needs

Reliable spawning and rearing techniques have been developed for several sturgeon species (Doroshov, 1985; Doroshov and Binkowski, 1985; Conte *et al.,* 1988; Williot, 1990). However, culturing larval sturgeon is difficult because the specific nutritional requirements for sturgeon larvae have not been determined and the use of formulated diets versus live food at the start of exogenous feeding is still being debated (Buddington and Christofferson, 1985). In addition, research is needed to identify and control diseases (*e.g.,* white sturgeon iridovirus, herpes I, and herpes II; LaPatra *et al.,* 1999) common to sturgeon in the early-life-history stages. However, despite all precautions at the hatchery to prevent pathogens, aquacultured fish could still introduce disease to wild stocks (ASMFC, 1992). Many sturgeon pathogens that adversely affect fish in culture settings are widespread throughout the geographic range of sturgeon (P. Anders, University of Idaho, Aquaculture Research Center, and S.E. LaPatra, Clear Springs Foods, Research and Development, personal communications). However, the risk of introducing disease to wild sturgeon populations needs to be weighed against the risk of extirpation of sturgeon populations if stocking is not attempted.

For successful aquaculture of sturgeon, further research is also required to synchronize the spawning times of sturgeon males and females, reduce the stress caused by handling, identify optimal fish sizes for stocking, determine best time(s) of year for stocking, and determine the best habitat and microhabitat release sites. Research is currently being conducted at the University of Florida, Gainesville, to determine oxygen requirements of different-sized sturgeon under different temperature and current regimes, the least invasive way to remove eggs from sexually mature sturgeon, and sturgeon's nutritional requirements in captivity (Appendices B, C). However, research is still needed to determine the nutritional and habitat requirements of sturgeon in all life stages, not just those of adults. By monitoring sturgeon hatchery releases, researchers could learn more about these basic requirements. A pilot project is currently being conducted to determine the movements, habitat use, feeding, and distribution of cultured subadult gulf sturgeon in selected habitats of the upper (above the dam) and lower (below the dam) Hillsborough River (Appendix C). However, genetic analyses to determine the factors that define a distinct population and assurance of sufficient habitat are essential before sturgeon should be stocked in large numbers (T. Rien, Oregon Department of Fish and Wildlife, personal communication).

Criteria to Examine

In transplanting or stocking sturgeon, as in stocking other fish, it is important to determine what the acceptable boundaries for transplanting are, such as stock condition and man's societal proclivities (T. Rien, Oregon Department of Fish and Wildlife, personal communication). In implementing a stocking program, several criteria need to be met to ensure that aquaculture practices do not adversely affect wild sturgeon populations: (1) a policy specifying the guidelines for stocking and protocols for breeding; (2) determination of the minimum size of the wild population stock before initiating stocking; (3) development of a rationale for augmenting segments of wild populations with stocked sturgeon; (4) determination of the physical, chemical, and biological factors necessary to maintain the growth, health, and genetic diversity of the sturgeon population; and (5) evaluation of survival of stocked sturgeon to determine the degree of success of the sturgeon restoration.

HABITAT USE AND COMPETITION

Before a river is stocked, the habitat the sturgeon require needs to be compared with the habitat present. An important consideration is what level of stocking can the habitat support? According to T. Rien (Oregon Department of Fish and Wildlife, personal communication), one of two contrasting strategies can be used. The first strategy is the camel's back approach: stock the habitat until the effects of sturgeon overcrowding are observed. However, this method does not tell much about what effects sturgeon may have on the environment or on other native species. An added problem of this approach is that reductions in sturgeon growth can be misinterpreted as being density dependent when in fact they may not be. The second approach is the bioenergetics approach: model the ecosystem and determine how many sturgeon the habitat can support based on the estimated availability of resources in the system. The biggest problem with this approach is that the uncertainty in many model parameters means it could take researchers many years of fieldwork to be able to answer this question. For example, in Oregon, much work would be needed to describe the diet and food values of poorly studied resident fishes that might be affected by increased sturgeon abundance and the resulting competition for food or space. It is difficult to acquire funding to better describe habitat availability and food preferences for sturgeon in the Pacific Northwest, because the work does not have a high enough priority among the fisheries projects competing for money there.

Although hatchery and wild environments could share similarities such as water quality and photoperiod, they most likely will differ markedly in terms of food type and amount, substrate type, fish density, water temperature and flow, competitors, and predators. Therefore, small pilot-stocking programs need to be conducted and monitored before large-scale efforts are carried out over broad geographical areas (ASMFC, 1998).

The hatchery-released stocks need to be monitored on a long-term basis to determine the sturgeon population's ability to survive in the natural environment. In addition, the effects of these stocks on wild cohorts and other fish populations in the receiving waters need to be evaluated. Because of the uncertainty of whether stocked sturgeon would cause the extinction of native sturgeon stocks, the uncertainty about the habitat's suitability for the introduction of cultured fish, and the lack of knowledge of the nature of imprinting in sturgeon, reintroduction of sturgeon to systems is controversial. Because gulf sturgeon occur as genetically discrete stocks, many parts of any restoration program, including the option of whether to allow the population to recover naturally or to restock, must be decided upon on a stock-by-stock basis.

STOCKING PROS AND CONS

Blankenship and Leber (1995) have formulated a concept for a responsible approach to developing, evaluating, and managing stock-enhancement programs. One important component of their approach to stocking sturgeon includes developing a management plan that identifies stock-rebuilding goals and genetic objectives and that defines quantitative measures of success. Hatchery fish must be identified, economic and policy guidelines should be followed, and the anadromous life history and late age of sexual maturity of gulf sturgeon need to be considered. Stocking is not the only or the most viable way to restore sturgeon populations—other alternatives need to be considered. Stocking is not an option if there are insufficient quantities of stockable juvenile sturgeon or if sturgeon populations have been so depleted that management agencies, which have prior commitments to maintain fisheries for other fishes, are unwilling to commit funding to develop sturgeon stock-enhancement programs (Smith, 1990).

PROS

Several studies have demonstrated that stock enhancement can help the recovery of fish populations that have been depleted by overfishing or by loss of essential habitat. Examples of these studies include those by Holt (1993), Heard *et al.* (1995), McEachron *et al.* (1995), Leber *et al.* (1996), Leber and Arce (1996), and Munro and Bell (1997). Enhancing sturgeon populations can supplement weak year-classes, aid in the recovery of endangered or threatened species, and increase our knowledge of wild stocks (Leber, 2000)[6]. Propagating and reintroducing sturgeon has aided in the restoration of depleted stocks of white sturgeon (Anders *et al.*, 1998; LaPatra *et al.*, 1999), lake sturgeon (*Acipenser fulvescens*), and paddlefish (*Polyodon spathula*) (Graham, 1986).

An experiment conducted in the Hudson River demonstrated that hatchery-produced Atlantic sturgeon can survive in the wild (Waldman and Wirgin, 1998). In a study lasting from 1986 to 1992, the South Carolina Department of Natural Resources tagged and released 18,213 hatchery-raised shortnose sturgeon in the Savannah River (Smith and Collins, 1996). In a survey made during 1990–1993, 35.4% of the shortnose sturgeon juveniles captured were stocked fish. This estimate may be conservative because some of the fish deemed to be "wild" sturgeon may actually have been stocked sturgeon that had not been tagged or had lost their tags. Results of this study indicate that hatchery-raised sturgeon may have high rates of survival. Therefore, it is likely that sturgeon populations can be restored through stock enhancement.

CONS

Although stock-enhancement programs have led to gains in fish production in some areas, the ability of these programs to yield self-sustaining increases in population abundance is largely unproven (Matthews and Waples, 1991; Nehlson *et al.*, 1991; Leber, 1999). Such increases are usually the result of permanent improvements in survivorship and in the carrying capacity of the environment (Tringali and Bert, 1998). The beluga sturgeon (*Huso huso*) population in the Sea of Azov is maintained only by the release of juvenile fish from commercial sturgeon farms, and the size of the Caspian Sea sturgeon population depends on the number of juvenile sturgeon released (Pirogovski *et al.*, 1989, cited in Birstein, 1993). There are at least two disadvantages of using programs to enhance wild stocks: (1) stock enhancement's ability to yield lasting and self-sustaining increases in population abundance is largely unproven and (2) stock enhancement is often used as a last resort when other, more expensive, options don't work (Leber, 2000)[6]. For example, the Russian sturgeon (*Acipenser gueldenstaedti*), the stellate sturgeon (*A. stellatus*), and the beluga sturgeon are threatened in spite of artificial-breeding and propagation programs (Barkova, 1987, cited in Birstein, 1993). The decrease in the natural production of these species is also a result of dams, uncontrolled logging, pollution, canals, and other environmental changes (Birstein, 1993). Thus, the goal of the USFWS and GSMFC (1995)—to restore gulf sturgeon populations to a commercially sustainable fishery—may be short-lived, if restoration of the populations is principally a result of supplemental stocking without concomitant habitat improvements. At the Florida Sturgeon Culture Risk Assessment Workshop, April 6–7, 2000 (Metcalf and Zajicek, 2001; Appendix B), much discussion led to the popular opinion that what is needed for native sturgeon species is a State of Florida Stock Restoration Plan that is consistent with the Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995) and Final Recovery Plan for the Shortnose Sturgeon (Shortnose Sturgeon Recovery Team, 1998).

Stocking Summary

Stocking gulf sturgeon in order to restore sturgeon populations can be feasible only if broodstock can be obtained without depleting the native gulf sturgeon population to the point that reproduction is affected. However, we cannot assume that small populations can be completely restored or rehabilitated through natural reproduction. Stocking can be successful only if habitats are present for sturgeon in all life-history stages, if the cultured sturgeon survive and reproduce, and if the introduced fish do not outcompete or displace native sturgeon or other native fish species in the

[6]Leber, K. M. 2000. Stock enhancement: Obsolete management concept or a new science? Powerpoint presentation presented at the National Academies Ocean Studies Board 41st Meeting, February 10–11, 2000.

ecosystem. Cultured sturgeon to be stocked should be genetically appropriate and physically healthy. Stocking protocols need to be developed based on the "responsible approach" concepts of Blankenship and Leber (1995). Small-scale projects need to be conducted and evaluated before large-scale projects are undertaken. For example, a breeding plan that includes culture methods for minimizing the detrimental effects that cultured sturgeon can have upon wild sturgeon has been implemented for Kootenai River white sturgeon. The purpose of this program is to guide managers in the systematic collection and spawning of wild sturgeon adults before they become extinct (P. Anders, University of Idaho, Aquaculture Research Institute; S. Ireland and J. Siple, Kootenai Tribe of Idaho Fisheries Department, personal communications). Success of the Kootenai River program will be determined by (1) an increase in the number of juvenile white sturgeon in the system, (2) the survival of hatchery-produced fish to sexual maturity, (3) retention of wild sturgeon life-history and population-genetics characteristics, and (4) an increased understanding of white sturgeon life-history characteristics and of the factors limiting natural recruitment (P. Anders, University of Idaho, Aquaculture Research Institute; S. Ireland and J. Siple, Kootenai Tribe of Idaho Fisheries Department, personal communications). A similar program could be adopted for gulf sturgeon in Florida.

Aquaculture of Sturgeon for Food

The development of a commercial sturgeon aquaculture industry in Florida would be a legal and enforceable way for farmers to sell sturgeon and could help reduce the clandestine fishing pressure on wild stocks of gulf sturgeon. The most authoritative manual on culturing North American sturgeon currently available is the "Hatchery Manual for the White Sturgeon (*Acipenser transmontanus*)" published by the University of California, Davis (Conte *et al.,* 1988). On May 27, 1999, the ASMFC issued a federal order banning the fishing of all sturgeon species from Maine to Florida. Also, in Florida, because of the restrictions imposed by the Endangered Species Act on shortnose sturgeon (which is endangered) and gulf sturgeon (which is threatened), it would not be practical to commercially rear them because they cannot be used in interstate commerce. Therefore, either Atlantic sturgeon (native to the east coast of Florida) or nonnative sturgeon are the primary candidates to be used in commercial aquaculture. If nonnative or hybrid sturgeon are cultured in Florida, the culture facility should be restricted to those operations that prevent the fish from escaping and reproducing (ASMFC, 1992). The ASMFC has developed a fishery management plan for Atlantic sturgeon that includes a section on adaptive management, which would allow for commercial culture. The State of Florida has proposed taking advantage of this adaptive management policy, and on January 31, 2001, the addendum to Amendment One of the Atlantic Sturgeon Fishery Management Plan was approved. This approves Florida's request to import non-U.S.-origin Atlantic sturgeon for private commercial aquaculture.

Any operation that cultures sturgeon in Florida must comply with the Best Management Practices (BMPs) for aquaculture, which are regulated by the Florida Department of Agriculture and Consumer Services (FDACS). These BMPs require farmers to prevent the sturgeon from escaping during any of its life-history stages. In order to prevent escape of sturgeon while they are being cultured as food, facilities must have biosecurity features (*e.g.,* covered tanks and ponds or a recirculating and a fully recycled system with containment berms, predator-stocked retention ponds, screened discharge pipes, and disinfecting procedures) and either be located inland, away from any chance of flooding, or be designed so that the facility is located above the 1,000-year flood plain elevation. A fence and a 0.9–1.2-m deep ditch should be constructed at each aquaculture site to prevent the sturgeon from escaping. Sturgeon farmers are required to notify FDACS of any unusual or abnormal occurrences of disease or pests affecting sturgeon being cultured. These precautions need to be taken to prevent nonnative sturgeon or their diseases and parasites from escaping to the wild and affecting native sturgeon populations, but none of the precautions have been fully tested, so no specific data are available to indicate which are best. However, it is unlikely that sturgeon will escape to the wild if a combination of safety features to reduce risk is used at every facility.

Florida Sturgeon Production Working Group

In 1996, the Florida Sturgeon Production Working Group (FSPWG) was created by legislation, F.S. 370.31, to examine the feasibility of both commercially culturing sturgeon for food and using commercially cultured sturgeon to enhance wild stocks. If one or both of these enterprises seem feasible, the working group will help develop recommendations about how best to commercially produce sturgeon for food and/or stock enhancement. In carrying out these two tasks, the working group established a State of Florida Sturgeon

Table 9. *The federal, private research, university, and public facilities in Florida that have captive sturgeon.*

Institution	Number and Species
U.S. Fish and Wildlife Service Welaka Fish Hatchery	1,156 gulf
Mote Marine Laboratory, Sarasota	9,500 bester, 1 Russian
University of Florida, Gainesville	570 gulf, 151 shortnose, 49 Russian, 2 beluga
University of Florida, Blountstown	596 gulf, 210 shortnose, 1,829 Atlantic, 15 shovelnose
Lowry Park Zoo, Tampa	7 gulf
Florida Aquarium, Tampa	4 gulf

Production Management Plan. The FDEP, in collaboration with FDACS, the Florida Game and Freshwater Fish Commission, and the University of Florida, Gainesville, presented a plan on "Implementation for the Commercial Culture and Conservation of Native Sturgeon in Florida" to the FSPWG on March 4, 1999. This plan, revised in July 1999, outlines the State of Florida's proposed directions for commercially culturing sturgeon. The FSPWG also needed to establish regulatory policies and BMPs. They initiated these steps at the Sturgeon Aquaculture Risk Assessment Workshop April 6–7, 2000; FDACS established regulatory policies and BMPs as a result of this workshop (Metcalf and Zajicek, 2001). Research priorities for sturgeon aquaculture have been determined by the FSPWG and are continually being revised. The FSPWG is also responsible for the development of a cooperative sturgeon conservation program. The FWC has assumed a lead role in protecting sturgeon by developing The State of Florida Conservation Plan for Gulf Sturgeon.

Permits for Possession and Culture

Initially, the FWC was authorized to issue special-activity licenses in accordance with section 370.06 section 4(b) F.S. and s.s. 370.31 F.S. for possession of anadromous sturgeon. The FWC was also authorized to issue special-activity licenses to permit the possession and aquaculture of native and nonnative anadromous sturgeon until BMPs are implemented for the cultivation of anadromous sturgeon pursuant to s.s. 597.004 F.S. This authorization was transferred to FDACS as of July 1, 2000. Table 9 documents the federal, private research, university, and public facilities that have sturgeon in Florida as of September 2000.

PRIVATE STURGEON AQUACULTURE PERMITS

The FWC also issued private permits for the commercial aquaculture of sturgeon. As of August 2000, these permits allow the culture of native gulf and Atlantic sturgeon, nonnative white and Russian sturgeon (*Acipenser guldenstadti*), and hybrid sturgeon. Currently, there are three private operators who have sturgeon: one has 297 Atlantic sturgeon, one has 400 gulf sturgeon, and one has a caviar operation with 37,000 bester sturgeon[7] and 3,100 Siberian sturgeon (*Acipenser baeri*). The purpose of these operations is to raise sturgeon for both their meat and for their eggs (caviar). As of July 2000, FDACS became responsible for issuing permits for these commercial operations.

Sturgeon Aquaculture Risk-Assessment Workshop

Critics of sturgeon aquaculture have voiced concerns about the ecological risk(s) to native sturgeon species and associated ecosystems if eggs, larvae, juveniles, or adult nonnative sturgeon species escape to the wild. Therefore, FDACS, Division of Aquaculture obtained funding through FMRI to organize a sturgeon risk-assessment workshop (Metcalf and Zajicek, 2001). First, a questionnaire was sent to knowledgeable managers and biologists from state and federal governments, universities, and nongovernmental organizations to determine the most important risks to wild sturgeon populations posed by sturgeon aquaculture. From these questionnaires, risks were narrowed by FDACS to the most important four concerns of respondents: broodstock acquisition, hybridization, pathogens, and ecological competition (Appendix B). Before the workshop, FDACS formed a working group for each topic; each working group was composed of people from a range of disciplines, not just experts in that topic. During the two-day meeting, each working group attempted to reach a consensus on the degree of risk posed to native sturgeon populations by sturgeon culture. Each working group also generated a list of options to prevent the risks. Decision tools were de-

[7]The bester is a hybrid of the beluga (*Huso huso*) and the sterlet (*Acipenser ruthenus*) sturgeon.

veloped from those described in the Risk Assessment and Management Committee, Aquatic Nuissance Species Task Force 1996 report on, "Generic Non-indigenous Aquatic Organisms Risk Analysis Review Process."The decision-making tools integrate the elements of the risk assessment model into a matrix format. Matrices were developed for the hybridization, pathogens, and ecological risks topics. (See Metcalf and Zajicek, 2001, for more details.) The risks of each cultured life history stage to wild sturgeon were ranked as high, medium, or low. Also economic, environmental, and social impacts of cultured sturgeon to wild sturgeon were examined. A separate format was developed for the broodstock acquisition topic. Each group's recommendations were summarized for the rest of the participants at the workshop. These results were used to formulate BMPs for sturgeon aquaculture. The following are the summaries of ideas compiled by each working group of risks posed by each life-history stage of cultured sturgeon to native sturgeon.

BROODSTOCK ACQUISITION

The working group discussing broodstock acquisition was asked to answer three questions[8] to assess the effects that removing sexually ripe male and female gulf sturgeon from the wild might have upon native populations. The group decided to answer the three questions by examining what the probable effects would be of removing sexually ripe gulf sturgeon from the Suwannee River. Several members of the working group believed removing broodstock would not affect the donor population as long as sturgeon in all life-history stages were present in multiple locations throughout the river and estuary ecosystem. However, no consensus was reached on this issue. The removal of eggs from only one ripe female sturgeon is needed for breeding sturgeon for food; however, for conservation purposes, 5 females to 12 males has been the accepted ratio. For stock enhancement, 5 to 10 pairs of sexually mature gulf sturgeon using a 1:1 ratio would be suitable to provide genetically diverse progeny. To more accurately determine these numbers and ratios, a more detailed genetic assessment is needed of the Suwannee River gulf sturgeon population. The number of gulf sturgeon juveniles that are now in captivity is sufficient for aquaculture for food if these sturgeon mature to be viable broodstock.

[8](1) Would removal of broodstock negatively impact the donor population? (2) How many wild adult sturgeon can be removed and at what rate (numbers of fish and frequency) without negatively affecting existing populations? (3) How many genetically distinct male and female fish are required to produce genetically diverse progeny and successfully produce fingerlings or juveniles for a stock enhancement program?

Viable methods for mitigating the potential effects of collecting broodstock from wild sturgeon populations include (1) returning a certain number (yet to be determined) of sturgeon 7–10 cm in length to the river of parental origin to simulate natural recruitment; (2) removing broodstock only when natural recruitment is not possible; (3) using only noninvasive, nonsurgical methods to strip eggs; (4) taking only subadult sturgeon—however, wild subadult gulf sturgeon do not feed in captivity (W. Clark, University of Florida, Gainesville [retired], personal communication); (5) taking only broodstock during drought years, when natural recruitment is nil; (6) using cryopreservation of gametes; (7) restoring, conserving, and protecting spawning habitat; (8) requiring a state protocol for determining how ripe a sturgeon must be before it can be collected; and (9) educating the public about these issues.

Recommendations for future research include (1) population estimates and monitoring of gulf sturgeon in all Florida rivers, (2) genetic assessment of sturgeon progeny by DNA analysis, (3) lipid acid research to differentiate genetic origin of sturgeon species and to differentiate wild from farm raised sturgeon, (4) assessment of the survival of artificially spawned sturgeon, and (5) sonic telemetry studies to compare any differences in movements between male and female sturgeon that have had eggs/sperm removed with sturgeon that have not undergone surgery.

HYBRIDIZATION OF CULTURED STURGEON WITH WILD STURGEON

Hybrid crosses of cultured sturgeon that could interbreed with wild gulf sturgeon are wild gulf with cultured gulf, wild Atlantic with cultured gulf, cultured Atlantic with wild gulf, and wild Atlantic with cultured Atlantic. Other cultured nonnative sturgeon species would probably not survive in the wild because of their inability to tolerate the high summer temperatures and high salinities of the Gulf of Mexico habitats. The hybridization working group discussed genetic contamination of the wild stock; inability of regulations to ensure that cultured fish do not escape the culture facility and enter the wild; environmental conditions (*e.g.,* heat stress) and fish survival; potential benefits of release; and production of sterile fish. However, these discussions were mostly restricted to formulating criteria that would minimize the risks of hybridization.

These criteria, in order of importance as ranked by the working group, were (1) an escape-free facility with no offsite discharge of water or a facility with a flow-through system and recycled water; (2) a facility that is not located in a flood plain or in a force zone (along the coast) and that is restricted to culturing only the species occurring in the same watershed; (3) a facility that has bird netting or some other covering over tanks containing smaller-sized fish; (4) a plan of what to do with all sturgeon raised, including excess sturgeon; (5) a provision for broodstock development in a specialized facility; (6) a transport protocol for moving sturgeon from one facility to another; (7) restrictions allowing the transfer of live sturgeon only to individuals with permits; (8) ways to reduce natural mortality caused by environmental factors such as temperature and salinity; (9) ways to reduce mortality caused by habitat limitations such as dams and sedimentation; (10) efficient methods for sterilization, triploidy, or other reproductive containment; and (11) efficient methods to mark cultured fish with external or internal tags. Factors 1–9 are absolute requirements, and factors 10–11 are dependent upon location and species.

PATHOGENS

Pathogens pose risks not only to the aquaculture industry but also to native and nonnative sturgeon and other fishes. The pathogen working group felt that insufficient information on sturgeon pathogens exists to conduct an assessment of the risks pathogens pose. The principal viruses affecting sturgeon in Florida are the white sturgeon iridovirus, white sturgeon herpes virus I, white sturgeon herpes virus II, white sturgeon adenovirus, Infectious Hematopoietic Necrosis Virus, *Aeromonas salmonicida,* and *Nitzschia sturiones*. The three pathogens believed to pose the greatest threat to aquacultured sturgeon in Florida are all from white sturgeon—iridovirus, herpes I, and herpes II—but little research has been conducted on these pathogens. The working group strongly believed there would be less risk if native sturgeon species are cultured, but if nonnative sturgeon species are cultured, guidelines should be developed that address the specific use of each cultured sturgeon life-history stage and verify the health of each life-history stage.

Topics of importance to the pathogen working group included (1) using diagnostic techniques to identify specific sturgeon pathogens of concern; (2) evaluating the feasibility of using nonnative sturgeon for aquaculture in Florida because different sturgeon species could have pathogens not present in native populations; (3) creating a system for permitting, inspection, compliance, and monitoring; (4) using staff from existing research organizations to form sturgeon technical working groups; (5) considering banning the importation of nonnative sturgeon in certain life stages for aquaculture and using both national and international health certifications to minimize the risk of infecting native stocks; and (6) accurately recording reports of sturgeon pathogens and continually update existing pathogen data bases.

After considering these topics, the sturgeon pathogen working group proposed the following to ensure healthy populations of sturgeon in Florida: (1) establish a healthy environment; (2) identify pathogens of concern; (3) develop a protocol for diagnostic tests; (4) provide a training course for producers; (5) identify which laboratories will conduct diagnostic and screening tests; (6) include a health component in the permitting process, with a violation resulting in a revocation of the permit; (7) create a working group to develop a plan that would determine strategies and practices to incorporate pathogen risks into BMPs; and (8) ask the working group to oversee pathogen research.

ECOLOGICAL RISK

The ecological working group examined the effects of introducing nonnative sturgeon species into areas occupied by gulf sturgeon. The working group focused its discussion on the introduction of Atlantic sturgeon because it is neither threatened (as gulf sturgeon are) nor endangered (as shortnose sturgeon are). The group concentrated on two main risks that cultured Atlantic sturgeon pose to wild native gulf sturgeon: their escape from culture facilities and their subsequent establishment as a breeding population. In trying to determine the likelihood that sturgeon at any stage in its life history might escape, two criteria are important: the degree of control exercised over the environment in which that sturgeon is handled and the life stage of that sturgeon. Because juveniles are the most likely to be transported by the aquarium trade, they are the most likely to escape. In contrast, sturgeon eggs, which are kept in controlled environments, and adults, which have a higher economic value than juveniles do, are both handled carefully and are less likely to escape. The likelihood of aquacultured sturgeon establishing a self-reproducing population in the wild depends upon whether the sturgeon escape in large groups or as individual fish and where the escape occurs. However, the working group concluded that it was most likely that escaped individual sturgeon would hybridize with existing sturgeon rather than form a separate population.

The working group suggested seven measures for preventing or mitigating the escape of nonnative sturgeon from culture facilities: (1) facilities should use only sturgeon species and sturgeon stocks that occur naturally in the drainage in which the facility is located; (2) culture only those species that historically occur in the basin or drainage in which the culture facility is to be located—gulf sturgeon should be cultured in gulf drainages and Atlantic sturgeon should be cultured in Atlantic drainages; (3) locate culture facilities a reasonable distance from open waterways and out of the most frequent hurricane paths—there is less risk that sturgeon will escape from a facility located in a 500-year flood plain than from a facility located in a 100-year flood plain; (4) the facility should not have offsite drainage or discharge to offsite surface waters—it should instead consist of either inside tanks or covered raceways and should be fenced and have multiple containment systems, filters, sumps, settlement ponds, and predator ponds in case of escape; (5) the facility should have an emergency management plan in case of a flood and provisions for retaining stormwater and removing fish stocks; (6) aquacultured sturgeon need to be tagged so that escapees can be tracked, and the facility staff should also obtain a performance bond against disaster; and (7) the staff should be knowledgeable about transport protocols and consumer behavior in the sturgeon aquarium trade.

IMPLICATIONS OF THE WORKSHOP

The proceedings of the sturgeon risk-assessment workshop were used to develop BMPs, which will be followed in cultivating anadromous sturgeon pursuant to F.S. s.s. 597.004. This statute spells out the provisions for certifying the registration of the aquaculture facility, paying fees, identifying and selling the aquaculture product, and renewing licenses. A regulatory framework will also be developed and implemented to eliminate accidental and intentional introductions of nonindigenous sturgeon stock.

Aquaculture Summary

Aquaculture can be useful in helping to restore gulf sturgeon populations by quantifying the parameters necessary for sturgeon to be produced and reared. The knowledge gained by aquaculture researchers can be used to better manage existing populations of wild sturgeon. Culturing gulf sturgeon for human consumption will increase the need for vigilant law enforcement to protect wild sturgeon stocks from illegal harvest; the incentives for taking wild sturgeon can be decreased by imposing high penalties on poachers. An aquaculture industry, if managed well, also has the potential of helping to conserve sturgeon by returning some of its profits to government research programs. Introduction of disease, nonnative sturgeon species, hybrids, or inappropriate native sturgeon stocks to watersheds can be managed by implementing effective permitting programs and BMPs. The Florida Fish and Wildlife Conservation Commission is committed to a responsible approach to sturgeon aquaculture so as to aid in the conservation of native gulf sturgeon stocks.

Research to Restore Gulf Sturgeon Populations

According to the Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995), to facilitate the recovery of gulf sturgeon, it is necessary to determine (1) the essential ecosystem requirements of sturgeon, (2) the most effective ways to protect sturgeon populations and habitats, and (3) the most efficient ways to coordinate and facilitate exchange of information about sturgeon. The research detailed in the following sections will be conducted by university, state, and federal biologists from Florida, Georgia, Alabama, Mississippi, and Louisiana. Appendices E and F describe the work conducted to date in each basin system.

Essential Requirements and Population Status

HABITAT ANALYSIS

Habitats that are essential to each gulf sturgeon life stage need to be identified in river basins and contiguous estuarine and neritic waters. Researchers will initially determine bottom consistency (soft or hard) and sediment type (sand, silt, clay, cobble, rock, or detritus) in rivers and in estuaries in each watershed where gulf sturgeon are found. Researchers will also determine whether there are impediments to sturgeon survival—such as dams or impoundments, which block sturgeon migration; determine the degree to which the water body has been altered from its natural state; and determine the presence or absence of submerged aquatic vegetation, woody debris, or deadhead logs. Also, potential sturgeon spawning sites in each river system will be identified via the use of telemetric monitoring of breeding sturgeon and by egg sampling. Telemetric studies of gulf sturgeon have been conducted by Odenkirk (1989), Foster and Clugston (1997), Fox *et al.* (2000), and Parauka (2000, in progress; see Appendix C), and gulf sturgeon egg-sampling studies have been conducted by Marchant and Shutters (1996), Sulak and Clugston (1998, 1999), and Fox *et al.* (2000). Because sexually mature gulf sturgeon prefer to use specific habitats at certain times of the year, the distribution of available spawning habitat should be examined so researchers can assess which factors might contribute to spawning-site selection. So that the generality of the results of the studies proposed here can be validated, they should be compared with the results of other studies conducted on sturgeon species in other river systems.

POPULATION ESTIMATION

Sampling incorporating standardized methods needs to be conducted in each watershed known to contain or to have historically contained sturgeon so that the presence and population size or absence and likelihood of establishing viable sturgeon populations can be determined. Sampling should also be conducted during the times of year when sturgeon are likely to be found in certain habitats. If sturgeon are present in the ecosystem, both physical information about the habitat occupied by the sturgeon and biological information about the sturgeon themselves need to be collected. Physical information should include the location of the sturgeon (latitude, longitude, and depth), its position in the river or estuary (*i.e.,* choice of banks, estimated distance of the sturgeon from the shore), the water flow rate, water quality parameters, and any other relevant physical characteristics. If sturgeon are collected, biological information and samples should include a description of the external condition of the sturgeon, a photograph, length and weight measurements, and a fin clip for genetic analysis.

DATA FOR POPULATION MODELS

Baseline data on sturgeon population levels should include the following information: sturgeon stock status, year-class strength, composition of the spawning population (ratio of males to females), reproductive success, and juvenile production in coastal river systems known to have contained or to currently contain sturgeon. These baseline data can also be used to evaluate population assessment methods and models. M. Allen at the University of Florida, Gainesville, is constructing a population model for gulf sturgeon in the Suwannee River (Appendices B, C).

LIFE–HISTORY STUDIES

Adult sturgeon have been successfully tracked with radio and sonic transmitters for several months in both riverine and estuarine systems (USFWS and GSMFC, 1995), but little is known about the ecosystem requirements of gulf sturgeon gametes, eggs, larvae, and juveniles less than a year old because of the difficulty in collecting sturgeon in these life stages from the wild (USFWS and GSMFC, 1995). Laboratory studies need to be conducted on sturgeon in these life-history stages to determine the minimal and the optimal conditions for their survival (D. Parkyn, University of Florida, Gainesville, is currently conducting some of these studies; Appendices B, C), and it is critical that these studies be a top priority (American Fisheries Society [AFS] Annual Meeting, Sturgeon Symposium, 23–24 August 2000).

STURGEON DIET AND DISTRIBUTION OF BENTHIC PREY

The only major study conducted thus far on feeding habitats concerned the gulf sturgeon population in the Suwannee River (Mason and Clugston, 1993). In order to obtain stomach contents for dietary analyses, D. Parkyn and D. Murie from the University of Florida, Gainesville, have developed a lavage technique to pump gulf sturgeon stomachs (Appendices B, C). A reference collection of benthic species commonly consumed by sturgeon should be developed so that sturgeon stomach contents can be more easily identified.

In order to identify and protect sturgeon's essential estuarine and marine habitats, scientists first must document the distribution of benthic species consumed by subadult and adult gulf sturgeon. Florida's Inshore Marine Monitoring and Assessment Program (IMAP) at FMRI will produce a list of benthic "indicator" species from estuaries within Florida. The presence of these species and their abundances will serve to indicate to researchers the physical health of the estuary from which the benthos were sampled (G. McRae, FMRI, personal communication). The composition of the benthic community (abundance and species) in an estuary can determine whether or not an ecosystem could support gulf sturgeon. D. Murie and D. Parkyn, University of Florida, are characterizing the distributions of the benthic species that form the sturgeon's diet in Suwannee Sound, and R. Heard, University of Southern Mississippi (USM) Gulf Coast Research Laboratory, is characterizing the distributions of the benthic species that form the sturgeon's diet in the Choctawhatchee Bay (Appendices B, C). After analyzing the results of these studies, researchers should be able to determine which estuaries would be suitable for transplanted sturgeon and which would not.

MIGRATION AND FEEDING

Although multiyear tracking studies of gulf sturgeon in rivers and estuaries have been conducted in the Suwannee, Apalachicola, and Choctawhatchee systems, multiyear tracking studies of gulf sturgeon in Gulf of Mexico marine environments have never been made (USFWS and GSMFC, 1995). In order to document gulf sturgeon marine migration routes and to determine whether critical overwintering habitat and feeding locations exist for sturgeon in the Gulf of Mexico (Odenkirk, 1989), these studies must be conducted. Satellite pop-off tags, which are attached externally to the sturgeon can be set to corrode at different rates and thus pop off the sturgeon at different times and float to the surface (D. Parkyn, University of Florida, Gainesville, personal communication). An Argos satellite network receives data from the tag and then down-loads the data to a land-based computer. A tag can be programmed to collect data such as the fish's position and the water's temperature and conductivity. Although individual tags are expensive, ranging in price from $800 to $2,000, they could provide useful information regarding winter movements and habitat preferences of gulf sturgeon.

STURGEON PREDATORS

Predators of all sturgeon life-history stages need to be documented. Barred owls or ospreys may feed on YOY and juvenile sturgeon (K. Sulak, USGS, personal communication), and flathead catfish (G. Carmody, USFWS, personal communication) may prey on juvenile sturgeon. Other potential riverine predators include the alligator and the alligator gar (R. Heard, USM, personal communication). Alligators have bitten sturgeon caught in gillnets (J. Clugston, Save Our Suwannee, personal communication). Also, bull sharks occupy fresh and brackish water and bays, and because they are known to feed on small sharks and stingrays, they would probably eat a sturgeon (R. Heard, USM, personal communication). However, E. Cortes (NMFS, personal communication) has analyzed shark stomach contents and is not aware of any studies noting the presence of sturgeon in shark stomachs. Adult sturgeon are probably less vulnerable to predation than juveniles are because of their larger size and external scutes, which resemble heavy plates of armor.

LABORATORY EXPERIMENTS

Researchers throughout Florida and other gulf states (Appendices D, E, G) are conducting laboratory experiments to determine gulf sturgeon environmental tolerances, habitat requirements, and nutritional requirements. These experiments could be used to develop more efficient methods of culturing gulf sturgeon. FWC has funded (Appendix B) is funding (Appendix C), and will continue to fund (projects yet to be determined) research on sturgeon requirements. Laboratory research of the general life-history requirements must be conducted before we can protect sturgeon habitat and raise sturgeon more efficiently and cost-effectively. More research is especially needed on the life-history stages of sturgeon between the egg and the one-year-old juvenile, and this research will be a priority for future funding.

GENETIC DIFFERENCES

Research is needed to determine whether there are significant genetic differences between cultured and wild stocks, and a gulf-wide genetic assessment of sturgeon is needed so that geographically distinct stocks can be identified and managed (USFWS and GSMFC, 1995). Lipid and isoelectric protein profiles are currently being run on wild and cultured sturgeon species. These profiles will be used as references by law enforcement personnel who need to distinguish whether meat came from wild or cultured sturgeon (M. French, FDACS, Division of Food Safety, personal communication; Appendix C).

UNAUTHORIZED TAKE

Several researchers believe that gulf sturgeon are caught incidentally as bycatch in nondirected fisheries, which puts the sturgeon at risk of being injured or killed (USFWS and GSMFC, 1995). Anecdotal reports of sightings from fishers (Reynolds, 1993) have noted that gulf sturgeon are sometimes bycatch in shrimp trawls. The extent to which gulf sturgeon are incidentally taken as bycatch and the physical condition of released sturgeon will be unknown until observers are placed on shrimp trawlers in Choctawhatchee and Apalachicola bays. Tagging studies should also be conducted along with this project to determine the survival rates of sturgeon caught and released by shrimp trawlers. Additional studies are necessary to determine the particular places and times of year that poaching is a problem so that enforcement can be increased accordingly.

PHYSICAL REQUIREMENTS— WATER QUALITY AND SEDIMENT TYPE

Water quality problems, sediment overloads, and harmful chemical contaminants that accumulate in sediments need to be identified so that gulf sturgeon recovery is not impeded. Water quality and sediment composition of rivers should be assessed to determine whether conditions are suitable for all gulf sturgeon life-history stages. Water-quality parameters that should be measured include dissolved oxygen, flow rates, river levels, turbidity, temperature, hardness, pH, salinity, phosphate, nitrate, and conductivity. Periodic water-quality testing should be conducted both at different times of day and during different times of the year, because chemical concentrations are known to vary seasonally and be dependent on each other. Also, reducing sediment input from road construction is extremely important in protecting and enhancing sturgeon populations in Florida Panhandle rivers. Sediment can cause water to become turbid, clog gills, and suffocate eggs. Also, if the river is too shallow, sturgeon will not be able to move upriver to spawning sites or sites of thermal refuge. Bottom sediments can accumulate heavy metals, and because sturgeon are benthic feeders, they are susceptible to accumulating heavy metals. Therefore, muscle tissue and blood samples of sturgeon need to be examined for the presence and levels of heavy metals;

if levels of contaminants become too high, sturgeon will have poor health and retarded growth, and in extreme cases, can die (Bateman and Brim, 1995).

LAND ACQUISITION

To ensure that essential habitats, stream flow, and groundwater in-flows are protected for gulf sturgeon, whole ecosystems need to be identified and protected. The water management districts (WMD) and The Nature Conservancy have acquired land through either conservation easements with buffers around streams or through fee simple (outright) acquisitions. Since 1984, the NWFWMD has acquired approximately 60,703 hectares through land-acquisition programs, in many cases for restoration to more natural conditions (Purdum and Penson, 1998). The SWFWMD owns more than 105,200 hectares of lands of unique environmental value, most of which was purchased through the SOR and the WMLTF Preservation 2000 programs (Wheeler *et al.,* 1998). The habitats of these protected areas should be classified to determine whether this land can benefit sturgeon. If the protected land has sturgeon habitat, it could be compared to adjacent private property with sturgeon habitat to determine whether the habitat remains protected in both areas and is capable of supporting sturgeon. Also, resource managers should work together to protect sturgeon habitat by acquiring and purchasing sensitive land through water management district programs.

In addition to the WMDs, two Florida agencies also manage and protect lands—FWC and FDEP. The FWC develops plans for and manages five million hectares of land in Florida. Because many of these managed regions contain watersheds that have habitat suitable for gulf sturgeon, the State of Florida's land acquisition program could help protect vital gulf sturgeon habitat. The FDEP's Division of State Lands is also willing to work to preserve specific parcels of land to help gulf sturgeon recovery (M. Glisson, FDEP, Division of State Lands, personal communication).

RIVERINE HABITAT IMPROVEMENT

The gulf coast ecosystems in which gulf sturgeon evolved have changed. Riverine habitat may need to be restored and enhanced before gulf sturgeon populations can recover (USFWS and GSMFC, 1995). For example, evaluations need to be made of whether sturgeon are able to pass around dams, especially around the JWLD on the Apalachicola River and the Jackson Bluff Dam on the Ochlockonee River, to reach essential spawning habitat. Removal of the lowhead dam at the confluence of the Pea and Choctawhatchee rivers could enhance the Choctawhatchee gulf sturgeon population (F. Cross, FWC, Panama City, personal communication). Research is also necessary to assess the direct and indirect effects that blasting and dredging and in-river disposal of the resulting debris have upon all stages of sturgeon development, and solutions need to be developed to minimize the effects of these operations on sturgeon habitat.

Information Exchange

The most essential part of any project is the ability to successfully coordinate and facilitate the exchange of information between researchers and managers. Coordination of gulf sturgeon research and recovery activities will be conducted on a regional and a multiagency level, with all gulf states (Florida, Georgia, Alabama, Louisiana, and Mississippi) participating (Appendices D, E, and F). This multistate approach is needed because rivers often cross state boundaries, and river conditions in one state can affect river conditions in one or more of the other states. A regional workshop was held on September 13–14, 2000, to address and update federal gulf sturgeon research priorities and discuss gulf state research efforts. (Results of the workshop are summarized in Appendices E, F.)

Funding for the Recovery Program

Because funding sources are always scarce, there needs to be a lead office charged with securing funds dedicated to gulf sturgeon recovery activities. As funds become available, gulf sturgeon restoration projects will be implemented to achieve the objectives as described in the Florida conservation plan. The FWC's FMRI is the lead state agency, and the USFWS's Panama City office is the lead federal agency for this conservation and recovery effort. Dedicated funds from state and federal agencies have been secured annually for the past and present years of sturgeon research and, hopefully, will continue in the future.

Monitoring of the Recovery Program

The State of Florida Conservation Plan for Gulf Sturgeon provides guidance to biologists, managers, and policy-makers, yet it also must be flexible enough to allow modifications needed to achieve the ultimate goal of restoring gulf sturgeon populations; the results of the various restoration projects must be periodically evaluated to assess whether the plan is succeeding and to recommend future actions. Since the Gulf Sturgeon Recovery/Management Plan was developed in 1995 (USFWS and GSMFC, 1995), several of the recovery objectives have been implemented, and federal objectives have been combined with state research efforts (Appendices E, F); however, further modifications may be necessary, as detailed in the following recommendation section.

Recommendations

This section describes actions that will be addressed by federal, state, and university biologists and by managers and policy personnel based in Florida, Alabama, Georgia, Mississippi, and Louisiana. Florida personnel will annually evaluate priority issues affecting gulf sturgeon and will work with the FDEP's Division of State Lands, the Florida Natural Areas Inventory, the Florida Acquisition and Restoration Council, and the regional water management districts.

Gulf sturgeon will be considered for removal from federal listing if, by 2023, populations are shown to be self-perpetuating and efforts are underway to restore lost or degraded habitats (USFWS and GSMFC, 1995). Some subpopulations of gulf sturgeon (such as the one in the Suwannee River, which has a resident population of approximately 7,000 sturgeon) might be delisted sooner. However, if the gulf sturgeon populations in the Suwannee River and other rivers consist of predominantly immature fish, the effective breeding population is much smaller than population models have suggested (K. Sulak, USGS, personal communication). The strict regulation against removing gulf, Atlantic, and shortnose sturgeon from wild populations was implemented in Florida in 1984. The 1984 moratorium promoted the survival of the adult gulf sturgeon population, but more measures are needed to protect sturgeon in the critical early-life-history stages.

The Gulf Sturgeon Recovery/Management Plan listed three objectives and recommended that the first two be met before the gulf sturgeon is removed from the list of threatened species (USFWS and GSMFC, 1995). The first objective is to prevent further reduction of all existing wild populations of gulf sturgeon. The second objective is to establish (by 2023) the size at which gulf sturgeon populations can be delisted on a river-by-river basis. The third objective is to establish self-sustaining gulf sturgeon populations that are robust enough to withstand directed fishing pressure (USFWS and GSMFC, 1995). The following immediate, short-term, and long-term actions are needed to accomplish these three recovery objectives and will be implemented under the State of Florida gulf sturgeon program (USFWS and GSMFC, 1995).

Actions

IMMEDIATE ACTIONS

Actions deemed to be immediately necessary to restore gulf sturgeon include the identification of relic water-control structures, lowhead dams, dredging, siltation, and other impediments to sturgeon migration. In the future, fish-passage devices should be constructed on all these types of structures so that fish migration and spawning patterns are not altered. The dredging required to deepen channels for ship navigation and the silting resulting from this dredging will, where possible, be subject to appropriate permit conditions that mitigate impacts to sturgeon. Other impediments to sturgeon passage, including increased temperature or turbidity resulting from physical obstructions and point- and nonpoint-source pollutants, also need to be identified and mitigated in each watershed.

SHORT–TERM ACTIONS

Short-term actions involve conducting scientific studies to identify existing and potential problems in rivers and estuaries that may affect populations of sturgeon. These scientific studies should incorporate water-quality sampling at seasonal intervals to determine whether the basic requirements of gulf sturgeon are present. Substrate samples in rivers that historically have had or currently contain sturgeon should be collected to determine whether appropriate substrates are present in sufficient quantities to meet the requirements of gulf sturgeon in all life stages. For example, if the substrate is inappropriate or inadequate for spawning, appropriately sized gravel can be placed on sites where sturgeon have spawned in the past but that have been recently degraded by human activities.

Rivers and estuaries containing habitats suitable for sturgeon in any life-history stage should be sampled at times of the year that sturgeon in each particular life stage are known to occur. Existing silviculture and agriculture BMPs should be assessed and the changes required to improve sturgeon habitat in areas where these practices take place should be identified. BMPs for dirt-road maintenance have been recently developed and need to be implemented in areas that have had a history of sedimentation problems from unpaved roads, because sedimentation makes rivers shallow, which reduces the suitable habitat for sturgeon. Such short-term actions will help prevent further reduction of existing wild populations of gulf sturgeon (USFWS and GSMFC, 1995; Kirk *et al.,* 1998).

LONG–TERM ACTIONS

Long-term conservation and management actions to eliminate threats to sturgeon include improvement of riverine, estuarine, and marine habitats; periodic monitoring of habitats and sturgeon populations; and establishment of self-sustaining populations. Water quality must be improved by reducing nutrients, excess turbidity, and sedimentation and by increasing dissolved oxygen levels. Periodic monitoring of water quality is essential to determine whether water conditions (including nutrients and flow rates) change in ways that might affect the distributions of gulf sturgeon populations. Stream habitat structure (*e.g.*, sedimentation rates, substrate, and bank vegetation) and benthic invertebrate populations in estuaries and rivers also need to be monitored for any changes that could negatively affect gulf sturgeon.

Besides restoring and protecting the sturgeon's essential summer and nursery habitats, we need to ensure that sturgeon can get to their habitats by removing obstructions to migration or installing fish passage devices to move sturgeon around obstructions. Making these changes will require cooperation between landowners, user groups, and the scientific community. Permit requirements for development or industrial activities in rivers and estuaries with gulf sturgeon populations also need to be established.

Restoration of sturgeon populations through stocking should be conducted only after a thorough study has been conducted in the river to be stocked to determine whether appropriate sturgeon habitats are present in sufficient quantity for sturgeon in all life-history stages. Genetically suitable sturgeon (those from the river to be stocked) must be used in small-scale pilot stocking projects in which all sturgeon are tagged and monitored on a regular basis before full-scale stocking can occur. The ultimate goal of these long-term actions is to establish self-sustaining populations of sturgeon that can withstand anticipated fishing pressure (USFWS and GSMFC, 1995; Kirk *et al.*, 1998).

Questions regarding the restoration of sturgeon discussed at the American Fisheries Society Sturgeon Symposium August 23–24, 2000, included the following:

- What advantages does restoring sturgeon populations via restoring and managing essential habitat have over restoring sturgeon populations via direct stock enhancement?
- What criteria are readily measurable for evaluating these restoration programs and what are the thresholds for these criteria?
- Does the track record on sturgeon restoration suggest that significant recovery of sturgeon populations is feasible?
- What role will (or should) sturgeon aquaculture play in the conservation and restoration of sturgeon populations?

Several systems in which gulf sturgeon live, such as the Apalachicola and Ochlockonee rivers, would benefit if water-flow regulations were in place and enforced. However, the composition of life-history stages of gulf sturgeon populations in each system throughout the species' range needs to be defined first. Little is known about the early-life-history stages (eggs to age-1 fish), and we need to address this lack of data. Restoration of habitat is always a top task, and some spawning habitat could be improved in several Florida Panhandle river systems. For example, the Choctawhatchee River has a number of potential spawning areas that have been filled with sediment over the years and could be cleaned out and deepened. The areas essential for gulf sturgeon in each river system must be documented and protected. (F. Parauka, USFWS, is conducting a study to determine sturgeon spawning sites on Florida Panhandle rivers, Appendix C.) Some gulf coast river systems could benefit from introductions of cultured fish as long as the age structure of the introduced fish support sturgeon in all life-history stages.

Education and Information Exchange

PUBLIC OUTREACH

Volunteer citizen groups such as Save Our Suwannee and the Choctawhatchee Bay Alliance have helped increase the public's awareness of the importance of protecting gulf sturgeon habitats. These groups, as well as other nongovernmental organizations, such as The Nature Conservancy, Earthjustice Legal Defense Fund, the Sierra Club, Florida Wildlife Federation, and Florida Defenders of the Environment, have been informing the public about sturgeon management issues. Sturgeon for Tomorrow has a sturgeon-guarding committee that monitors habitat during the spawning season (three weeks in the spring) to prevent lake sturgeon poaching (D. Vogds, Sturgeon for Tomorrow, personal communication). Hillsborough Rivers Greenways Task Force has set up a committee to educate the public about the pilot project that monitors hatchery gulf sturgeon that were released in the upper (above the dam) and lower (below the dam) Hillsborough River. State of Florida agencies (FWC, FDEP, WMD), universities (University of Florida, Gainesville, has the lead), and federal agencies (USFWS and NMFS) are also working to gain public support for both conservation and aquaculture projects to enhance sturgeon populations.

SCIENTIFIC EXCHANGE

If we are to mitigate or reverse the water-quality and habitat degradation in the drainages of gulf rivers and estuaries essential to the survival of gulf sturgeon, scientists, managers, policy-makers, landowners, and stakeholders must freely and continually exchange data and information of activities on sturgeon conservation and recovery.

Summary

Management Objectives and Recommendations

According to the Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995), the main management objectives for gulf sturgeon are (1) to protect them from further stock depletion, including from incidental take as bycatch; (2) to gain more knowledge about the stocks; (3) to enhance and restore stocks; and (4) to coordinate research and management activities throughout the species' range.

The plan also recommended that critical habitat be identified and protected, that sturgeon movements be documented, that the status and genetic characteristics of sturgeon populations be evaluated, that propagation techniques for sturgeon be developed, and that the health and genetic make-up of hatchery sturgeon be evaluated for stock-restoration purposes. This conservation plan will be used to aid and guide the recovery of gulf sturgeon populations throughout Florida and could be used as a model in other gulf states. Our primary goal is to preserve existing wild stocks of gulf sturgeon by protecting their essential habitat, but enhancing some populations may require stocking.

Priorities

There are three priorities in protecting gulf sturgeon: (1) assess populations of wild gulf sturgeon, (2) manage habitats and populations on a watershed-by-watershed basis, and (3) identify, protect, and enhance essential habitats. The State of Florida has recognized these high-priority issues, has funded research in several of these areas (Appendix B), continues to fund such research (Appendix C), and will be funding upcoming research.

Management Strategies

Proposed management strategies aimed at conserving and restoring sturgeon populations focus on the protection of essential sturgeon habitats. To effectively manage gulf sturgeon, we need to identify their habitat needs and determine basic life-history requirements. We must define habitat requirements for sturgeon in terms of ecosystem-wide conditions so that sturgeon in all life-history stages can survive. By collecting sturgeon in different types of gear, each of which is designed to capture a different size range of fish (*e.g.,* gillnets, trammel nets, and trawls), and by tagging and subsequently monitoring fish with radio and acoustic telemetry equipment, researchers can determine which habitats are used by sturgeon in each life-history stage.

Sturgeon spawning sites are known in several river systems, and if we protect spawning habitats we will help to conserve existing sturgeon stocks. F. Parauka, USFWS, is surveying Florida Panhandle river systems to determine the location of gulf sturgeon spawning sites (Appendix C). Artificial substrates should be created to encourage spawning where natural substrates have been destroyed. Required habitats for sturgeon in other life-history stages may be more difficult to determine. To protect and restore sturgeon's essential summer and nursery habitat, we need to reduce nutrient and sediment inputs to river systems (Collins *et al.,* 2000) and reduce the degree to which sturgeon habitat is modified by such activities as dredging and damming rivers.

Systemwide Habitat Needs

Because sturgeon require a broad range of habitats, only large-scale, systemwide habitat protection and improvement programs can provide benefits and ensure the survival of sturgeon populations (Beamesderfer and Farr, 1997; Haywood, 1998). Measures for improving sturgeon habitat include facilitating the passage of sturgeon around dams, increasing areas of spawning habitat, establishing minimum water-flow regimes, reducing silt loads, and improving water quality. These measures may also benefit other organisms. However, the options for producing systemwide changes that benefit sturgeon are often limited because they involve complex issues of water diversion and land use. The implementation of these options is also complicated by economic (they are expensive) and social concerns.

Stock Enhancement

Before stock enhancement can be used to the best advantage in restoring sturgeon populations, policies and guidelines for stocking hatchery-reared sturgeon into the wild need to be developed. Sturgeon should be stocked into existing populations only when regional wild stocks are near extirpation and anthropogenic impacts cannot be corrected before populations are severely depleted (Kynard, 1997). So that the genetic integrity of the local recipient sturgeon stock is maintained, broodfish used to produce sturgeon for stocking should be taken from the regional genetic group to which sturgeon in the area being stocked belong or from adjacent, hydrologically similar river systems. In addition, if sturgeon are cultured for restoration purposes, an adequate effective captive breeding population size should be maintained.

The FWC will engage in a partnership with the USFWS and the NMFS to explore the feasibility of implementing a pilot-scale stocking program to replenish decimated populations of gulf sturgeon. Such a stocking program should be attempted only if suitable and sufficient habitat conditions for sturgeon in all life-history stages are present and if a long-term commitment of money and personnel is made so that the program's success—measured by the level at which the sturgeon in that population are reproducing—can be monitored.

Conclusion

Sturgeon are globally threatened because their eggs (caviar) and meat are highly valued and much of the sturgeon's riverine habitat has been degraded or destroyed by man. Restoring and protecting habitat in conjunction with stocking hatchery-reared sturgeon into the wild may sustain certain sturgeon populations. A commercial sturgeon aquaculture industry could help alleviate pressure on wild stocks from poaching, but it will also create enforcement challenges. Informational displays and the internet will keep the public and nongovernmental organizations informed about recovery efforts to restore sturgeon populations. To preserve and enhance sturgeon stocks for the long term, we need to reduce the number of sturgeon deaths caused by humans, and we need to identify, improve, and augment the sturgeon's essential habitats. We also need to study in detail the ecosystem requirements for sturgeon in all life-history stages and to monitor trends in individual populations. Supplementing some populations or reintroducing sturgeon to other areas may be necessary, but only after all basic requirements of sturgeon are known. Although habitat restoration is the most difficult and expensive recommendation to implement, it is the most important for maintaining gulf sturgeon populations in the long term (Haywood, 1998). Water management districts in Florida have studied purchasing or otherwise obtaining riparian corridor, which will help protect many gulf sturgeon populations.

Scientists from universities and state and federal agencies who study the recovery or commercialization of sturgeon populations in the Gulf of Mexico need to form partnerships and share information about research and recovery activities. This conservation plan will be useful to those involved in efforts to restore gulf sturgeon populations throughout the State of Florida and could also be used as a model for sturgeon restoration efforts in other gulf states.

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APPENDIX A

Maps of Estuaries and Rivers of the Florida West Coast

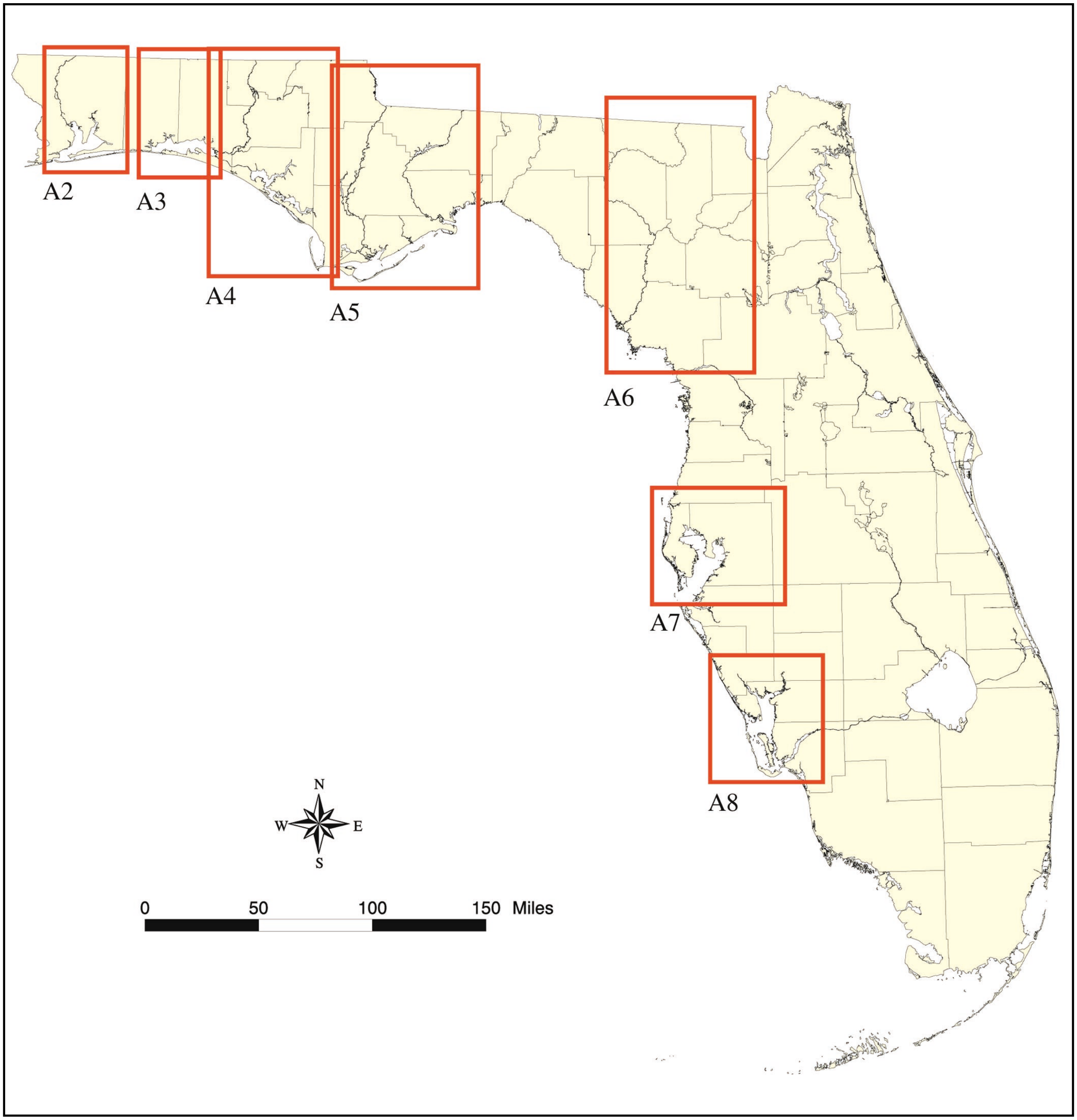

Figure A1. *State of Florida Map Index*

Figure A2. *Pensacola Bay System*

Figure A3. *Choctawhatchee Bay System*

Figure A4. *St. Andrew Bay to St. Joseph Bay*

Figure A5. *Apalachicola Bay System*

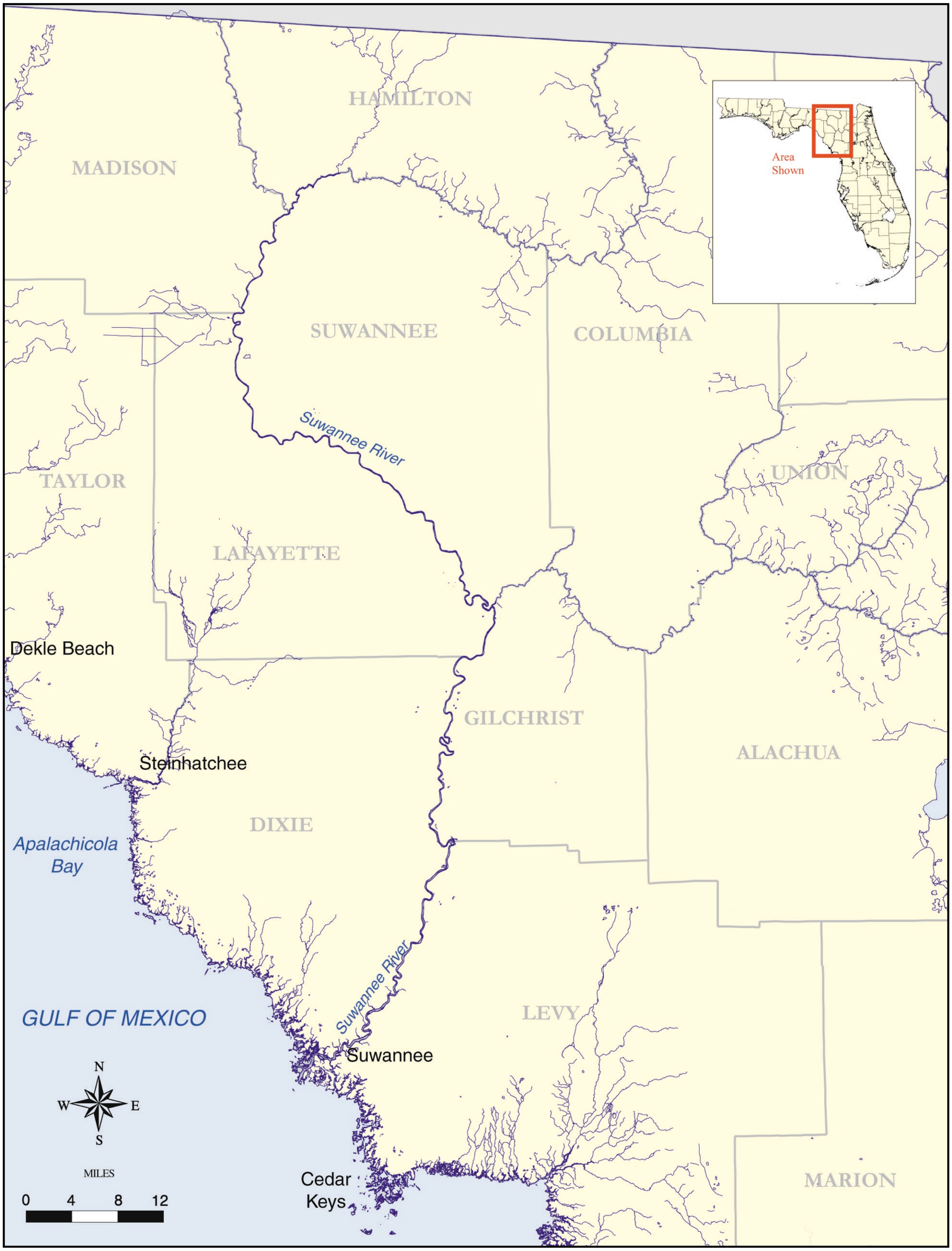

Figure A6. *Suwannee System*

Figure A7. *Tampa Bay System*

Figure A8. *Charlotte Harbor*

APPENDIX B

1999–2000 Sturgeon Research Funded by FWC

Projects 1–6

Contracting Agency: University of Florida

PROJECT 1
CONSERVATION AND CULTURE OF NATIVE STURGEON
This project involves collecting sturgeon from the wild, operating a hatchery to propagate sturgeon, maintaining captive broodstock, and producing a consistent supply of the larvae and juvenile sturgeon needed to conduct projects 2–6.
Principal Investigator
Douglas Colle

PROJECT 2
FEEDING STRATEGIES OF GULF STURGEON
This project involves developing and evaluating practical strategies for feeding and maintaining sturgeon in hatcheries and evaluating the effects of yeast-based protein on the performance of native sturgeon. The feeding parameters evaluated include the appropriate feed type and feeding times, the growth rate of sturgeon on various feeds, the optimal diets for different life-history stages of sturgeon growth, and the physiological parameters that affect feeding and feeding physiology. This laboratory research will allow sturgeon aquaculture techniques to advance from research technology to commercial aquaculture production of sturgeon.
Principal Investigators
Andrew Lazur, Richard Miles

PROJECT 3
SURGICAL TECHNIQUES FOR REMOVING EGGS IN SPAWNING STURGEON
This project involves refining surgical techniques for removing eggs in spawning sturgeon; researchers hope to improve the survival rate of broodstock sturgeon raised to produce fertilized eggs. In this study, researchers developed artificial ovarian fluid, expanded our knowledge of sturgeon anatomy, successfully operated and removed eggs using smaller (1″) incisions, and learned about the absorption times for both internal and external sutures following surgery.
Principal Investigator
Frank Chapman

PROJECT 4
NONLETHAL METHOD FOR COLLECTING STURGEON STOMACH CONTENTS
Nonlethal methods have been developed for collecting sturgeon stomach contents to assess feeding activities. Stomach contents of sturgeon have been collected by washing or lavaging the stomach, which eliminates the need to sacrifice the fish. Initially, this project was laboratory-based to evaluate the optimal amount of water needed to obtain the most stomach contents. The information learned from these laboratory studies is being applied to wild sturgeon during their upriver migration to assess the usefulness of the lavage technique for determining when sturgeon have the most and least food in their stomachs.
Principal Investigator
Debra Murie

PROJECT 5
POPULATION MODELING OF GULF STURGEON IN THE SUWANNEE RIVER
A simulation model will be developed to assess population dynamics of gulf sturgeon in the Suwannee River, Florida. This model will allow managers to assemble available data and make predictions of population trends for the Suwannee River stock of sturgeon. The population parameters analyzed will include growth, length of sturgeon at given ages, survival rates of sturgeon at different life stages, fecundity, and population estimates.
Principal Investigator
Mike Allen

PROJECT 6
ENVIRONMENTAL TOLERANCES OF STURGEON
Environmental tolerances and potential sources of mortality (upper lethal temperatures, dissolved oxygen, and current velocity) for sturgeon in different life stages are being studied. This research will provide information about the culture conditions necessary for captive sturgeon to survive. The farmer and researcher will be better able to optimize production (survival and growth) by maximizing efficiency and minimizing cost.
Principal Investigator
Daryl Parkyn

Projects 7, 8

Contracting Agency: U.S. Fish and Wildlife Service

PROJECT 7
NEW SURGICAL PROCEDURE FOR EGG EVALUATION AND THE EFFECTS OF MS222
Surgical procedures have been developed for evaluating the physiological effects of tricaine-methanesulfate (MS-222), Metomidate, and Eugenol anesthesia on the adult and eggs of shortnose sturgeon (*Acipenser brevirostrum*). This project addresses the same problems in shortnose sturgeon that Project 3 does for gulf sturgeon: the safe procurement of ovarian samples and the evaluation of egg maturity. In addition, the effects and potential benefits of using anaesthetics to reduce stress in female shortnose sturgeon was examined. Two highly desired products developed from this project are a fistula (portal) for repeatedly sampling ovarian maturation and an anaesthetic protocol to follow in determining effects of the anaesthetics on the cardiovascular system and egg quality.
Principal Investigators
Robert Bakal, Cliff Swanson

PROJECT 8
NEW SYSTEM FOR REARING SHORTNOSE STURGEON
A new system has been developed for rearing shortnose sturgeon (*Acipenser brevirostrum*) from egg to juvenile. This new system applies trout-rearing technology and methodology to sturgeon (use of a Heath incubator in a single rearing aquarium) and improves survival, reduces bloating disease, and improves feed efficiency. It also uses less water than previous rearing methods and increases the bottom surface area per sturgeon, thus improving production per unit of fish.
Principal Investigator
Robert Bakal

Project 9

Contracting Agency: Florida Department of Agriculture and Consumer Services

STURGEON CULTURE RISK–ASSESSMENT WORKSHOP
A two-day scientific and policy workshop on sturgeon-culture risk assessment was held to bring together researchers, managers, and policy-makers to discuss the risks of sturgeon aquaculture. The end product of the workshop was a document that will provide readers with information on the best management practices to use in sturgeon aquaculture, a guide to sturgeon policy and program development, and sturgeon aquaculture and stock enhancement protocols.
Principal Investigators
Paul Zajicek, Karen Metcalf

Project 10

Contracting Agency: Florida Department of Environmental Protection, Northwest Florida Aquatic Preserves

IDENTIFY SPAWNING HABITATS OF STURGEON IN YELLOW AND ESCAMBIA RIVERS
Gulf sturgeon spawning habitats in the Yellow and Escambia river systems will be identified. Biologists will use radio and sonic tags to track sturgeon. This project will provide information about sturgeon riverine habitat and where to place egg-collection devices.
Principal Investigator
Nadine Craft

Project 11

Contracting Agency: Gulf Coast Research Laboratory

DETERMINE DISTRIBUTION AND ABUNDANCE OF BENTHOS IN CHOCTAWHATCHEE BAY
The distribution and abundance of bottom-feeding invertebrates (shrimps and worms), the primary food of gulf sturgeon of Choctawhatchee Bay, will be compared to the seasonal occurrence and spatial distribution of gulf sturgeon in the bay. In this project, researchers will investigate the feeding ecology of sturgeon by identifying the food organisms preyed upon by sturgeon and by determining whether the presence or absence of these organisms affects sturgeon distribution in this shallow bay system.
Principal Investigator
Richard Heard

APPENDIX C

2000–2001 Sturgeon Research Funded by FWC[1]

Projects 1–5

Contracting Agency: University of Florida

PROJECT 1
CONSERVATION AND CULTURE
OF NATIVE STURGEON
Sturgeon will be collected from the wild to continue a hatchery for domestic stocks of native sturgeon (including captive broodstock and the production of a consistent supply of larvae and juvenile sturgeon). The fish collected during this project are necessary to conduct projects 2–5.
Principal Investigator
Doug Colle

PROJECT 2
ASSESS THE POST–RELEASE SURVIVAL AND MOVEMENT OF GULF STURGEON THAT WERE USED AS BROODSTOCK IN ARTIFICIAL PROPAGATION
Sexually mature sturgeon that have been surgically biopsied will be tracked sonically for 4–6 months after release to determine whether artificial spawning protocols affect survival of the sturgeon or their ability to otherwise join the upstream seasonal migration.
Principal Investigators
Daryl Parkyn, Debra Murie, Doug Colle

PROJECT 3
POPULATION MODELING OF GULF STURGEON IN THE SUWANNEE RIVER
A computer model will be developed to determine the population trends of gulf sturgeon in the Suwannee River. This model will be used to predict mortality and the recruitment levels required to sustain the Suwannee River population of sturgeon. The model could also be a useful tool in examining recovery criteria and may have applications to other gulf sturgeon stocks in other gulf coast ecosystems.
Principal Investigator
Mike Allen

PROJECT 4

DEVELOP AND IMPLEMENT A NONLETHAL METHOD FOR COLLECTING STOMACH CONTENTS FROM STURGEON IN RELATION TO FEEDING
The lavage technique developed in the previous contract was successful and sturgeon were found to be consuming exclusively brachiopods prior to entering the East Pass of the Suwannee River. Rates of stomach evacuation and digestion will be determined. Also, the distribution of brachiopod beds will be compared to the distribution of gulf sturgeon in Suwannee Sound.
Principal Investigator
Debra Murie

PROJECT 5
ENVIRONMENTAL TOLERANCES OF CULTURED GULF AND SHORTNOSE STURGEON COMPARED TO TOLERANCES OF WILD STURGEON
Data concerning the temperature, oxygen, and current velocity requirements of cultured sturgeon are currently being collected. Researchers plan to use this information to develop a temperature-logging device that will provide detailed information on the temperature of the water encountered by wild sturgeon throughout different phases of their freshwater and saltwater residencies.
Principal Investigator
Daryl Parkyn

Project 6

Contracting Agency: Florida Department of Environmental Protection, Northwest Florida Aquatic Preserves

IDENTIFY GULF STURGEON SPAWNING HABITATS IN THE YELLOW AND ESCAMBIA RIVERS
Continue sturgeon research on the Yellow and Escambia rivers to determine riverine migration patterns and spawning sites so that gulf sturgeon habitat can be identified and protected. Information obtained from the marine component of the study will be used to establish the habitat requirements of overwintering sturgeon.
Principal Investigator
Nadine Craft

[1]Projects 1, 3, 4, 5, 6, 7, and 9 are continued from 1999–2000 funding.

Project 7

Contracting Agency: Gulf Coast Research Laboratory

DETERMINE DISTRIBUTION AND ABUNDANCE OF BENTHOS IN CHOCTAWHATCHEE BAY, SUWANNEE SOUND, AND PENSACOLA BAY
Continue to compare and contrast the benthos of Choctawhatchee Bay with the foraging areas of gulf sturgeon in both shallow and deep-water areas of the bay. Compare the benthos and gulf sturgeon foraging areas of Choctawhatchee Bay with the benthos and foraging areas of gulf sturgeon in Suwannee Sound and Pensacola Bay.
Principal Investigator
Richard Heard

Project 8

Contracting Agency: Florida Department of Agriculture and Consumer Services, Division of Aquaculture

STURGEON MARINE FORENSICS TESTING
A fatty acid lipid laboratory-based test will be developed to differentiate cultured from wild sturgeon meat. This test will be performed on cultured gulf, Atlantic, shortnose, and white sturgeon and will be used by law enforcement personnel to deter poaching and the marketing of illegal products.
Principal Investigators
Paul Zajicek, Mark French

Projects 9, 10

Contracting Agency: U.S. Fish and Wildlife Service

PROJECT 9
EVALUATE THE SAFETY OF SOME COMMON THERAPEUTIC AGENTS
Evaluate the tolerance of gulf and shortnose sturgeon in various age-classes to therapeutic agents known to be effective against numerous aquatic pathogens in other fish. Also determine any pathology associated with the use of any of the following seven compounds: chloramine T, copper sulfate, diuron, formalin, hydrogen peroxide, potassium permanganate, and sodium chloride.
Principal Investigator
Robert Bakal

PROJECT 10
DOCUMENT GULF STURGEON ESSENTIAL HABITAT IN FLORIDA PANHANDLE RIVER SYSTEMS
Document available gulf sturgeon spawning habitat in Florida Panhandle rivers (Escambia, Blackwater, Yellow, Choctawhatchee, Pea, Apalachicola, and Ochlockonee rivers) and create a map identifying known gulf sturgeon spawning sites that have characteristics similar to previously documented spawning sites.
Principal Investigator
Frank Parauka

Project 11

Contracting Agency: Mote Marine Laboratory

DOCUMENT MOVEMENTS, HABITAT PREFERENCES, GROWTH RATES, AND SURVIVAL RATES OF HATCHERY– REARED SUBADULT GULF STURGEON IN TWO REACHES OF THE HILLSBOROUGH RIVER, FLORIDA
Partnership between Mote Marine Laboratory and FMRI to enhance overall experimental design of the Hillsborough River study. Researchers will provide expertise to help adapt state-of-the-art tagging technology for marking subadult gulf sturgeon and provide personnel and expertise to successfully monitor and track sturgeon.
Principal Investigators
Ken Leber, Carol Neidig, Sondra Graves

APPENDIX D

Organizations and Stakeholders Interested and Involved in Gulf Sturgeon

A. Florida Government Agencies
   1. Florida Fish and Wildlife Conservation Commission
      a. Florida Marine Research Institute, St. Petersburg (Alan Huff, Anne Wakeford, Dan Roberts, Mike Tringali)
      b. Tallahassee (Robert Palmer, Ted Hoehn)
      c. Lake City (Julie Jones, Jerry Krummrich)
      d. Deleon Springs (Jay Holder)
      e. Panama City (Fred Cross)
      f. Richloam Fish Hatchery (Rick Stout)
   2. Florida Department of Environmental Protection
      a. Northwest Aquatic Preserves, Milton (Nadine Craft)
      b. Tallahassee (Joe Hand, Russ Frydenbourg)
      c. Pensacola (Donald Ray)
   3. Florida Department of Agriculture and Consumer Services, Division of Aquaculture
      a. Tallahassee (Mark Berrigan, Paul Zajicek, Karen Metcalf)
      b. Food Safety Laboratory, Tallahassee (Mark French)

B. Federal Organizations in Florida
   1. United States Fish and Wildlife Service
      a. Panama City (Gail Carmody, Frank Parauka, Jerry Ziewitz)
      b. Welaka National Fish Hatchery (Alan Brown)
   2. National Marine Fisheries Service, St. Petersburg (David Bernhart, Jennifer Lee)
   3. United States Geological Service
      a. Biological Resource Division, Gainesville (Ken Sulak, Ann Foster)
      b. Regional Offices
         (1) Northwest Florida, Tallahassee (Marvin Franklin, Darlene Blum)
         (2) Southwest Florida, Tampa (Yvonne Stoker); St. Petersburg (Randy Edwards)
   4. United States Army Corps of Engineers
      a. Jacksonville (Bill Fonferek)
      b. Mobile (Mike Eubanks, Brian Peck)

C. Florida Universities
   1. University of Florida, Gainesville (Frank Chapman, Mike Allen, Doug Colle, Debra Murie, Daryl Parkyn)
   2. University of Florida, Blountstown (Andy Lazur, Debra Britt-Pouder)
   3. University of Florida, Tropical Aquaculture Laboratory, Ruskin (Dan Bury)
   4. Florida State University, Tallahassee (Robert Livingston)
   5. University of Tampa (Wayne Price, Karen Strasser)

D. Private Organizations in Florida with Sturgeon Aquaculture
   1. Mote Marine Laboratory (Ken Leber, Steve Serfling, Carol Neidig, Sondra Graves)
   2. Private sturgeon farmers
      a. Rokaviar Fish Farm
      b. Evans Farm
      c. Paul's Fish Farm

E. Florida Representatives and Senators
   1. District Representative Robert L. Pickles (for Representative Boyd)
   2. Senator John F. Laurent

F. Florida Water Management Districts
   1. Northwest District, Havana (Tyler MacMillan)
   2. Southwest District, Brooksville (Joseph Quinn, Sid Flannery)
   3. Suwannee District, Live Oak (Rob Mattson, David Hornsby)

G. Florida Land-Preservation Organizations
   1. FDEP Division of State Lands, Tallahassee (Mark Glisson)
   2. Florida Natural Areas Inventory, Tallahassee (Amy Knight)
   3. The Nature Conservancy, Jay (Vernon Compton, Stephanie Davis)

H. Florida NGOs
   1. Earthjustice (David Guest, Ansley Samson)
   2. Sierra Club (Judy Hancock, David Auth)
   3. Florida Defenders of the Environment (Leslie Straub, Steven Carr)
   4. Save Our Suwannee (Jim Clugston)
   5. Florida Wildlife Federation (Manley Fuller)
   6. Choctawhatchee Basin Alliance (Ross Hamilton)
   7. Hillsborough Rivers Greenways Task Force (Laura Delise)
   8. Nature's Classroom (Mike Mullins, Karen Johnson)

I. Other Gulf State Organizations
   1. Geological Survey of Alabama (Scott Mettee)
   2. Mississippi Museum of Natural Science (Todd Slack)
   3. Louisiana Department of Wildlife and Fisheries (Howard Rogillio, Bobby Reed, Libby Rabalais)
   4. Alabama Department of Conservation and Natural Resources

- a. Montgomery (Stan Cook)
- b. Marian (Philip Kilpatrick)
- c. Spanish Fork (Joe Zolczynski)

5. Mississippi Department of Wildlife Fisheries and Parks (John Skaines)
6. Georgia Department of Natural Resources, Albany (Russ Ober)

J. Other Federal Organizations

1. National Marine Fisheries Service, Silver Spring, Maryland (Marta Nammack)
2. United States Army Corps of Engineers
   - a. Vicksburg, Mississippi (Phil Kirk)
   - b. New Orleans, Louisiana (Larry Hartzog)
3. United States Fish and Wildlife Service
   - a. Atlanta, Georgia (Tom Sinclair)
   - b. Baton Rouge, Louisiana (John Forester)
   - c. Layfette, Louisiana (Whitney Granger, David Walthes)
   - d. Warm Springs Regional Fisheries Center, Georgia (Vince Mudrak, Robert Bakal)
   - e. Ocean Springs, Mississippi (Doug Fruge)
   - f. Daphne, Alabama (Larry Goldman, Carl Couret)
4. USGS Pautuxant Wildlife Research Center, Georgia (Mary Freeman)

K. Other Universities

1. University of Southern Mississippi
   - a. Ocean Springs (Richard Heard, Jerry McLelland, John Foster)
   - b. Hattiesburg (Steve Ross and Ryan Heise)
2. Mississippi State University (Wendell Lorio, Mike Pursley, Jay Becker)
3. North Carolina State University (Joe Hightower, Dewayne Fox)
4. Auburn University, Alabama (Elise Irwin)

L. Interstate Organizations

1. Gulf States Marine Fisheries Commission (Ron Lukens)
2. Atlantic States Marine Fisheries Commission (Heather Stirratt)

M. Other involved people

1. Private landowners
   - a. Dairy, poultry, tree, agriculture, and fish farmers
   - b. Other land owners
2. Corporations/industries
   - a. Wastewater and sewage treatment plants
   - b. Phosphate and cement industries
   - c. Road-building companies
   - d. Industrial plants (*e.g.,* power/electricity, carpet fibers)

APPENDIX E

Notes from the Gulf Sturgeon Workshop in Stennis, Mississippi, September 13–14, 2000
Priorities of the Gulf Sturgeon Recovery and Management Plan[1]

At the regional workshop on gulf sturgeon held in 1998, the following action items were deemed to be the most important for protecting and managing gulf sturgeon (listed here in the order in which the workshop members ranked them): (1) reducing incidental take of sturgeon by other fisheries; (2) identifying freshwater and marine habitats important to sturgeon; (3) protecting sturgeon habitats, both freshwater and estuarine/marine; (4) determining dietary requirements of sturgeon; (5) determining sturgeon population levels; (6) providing fish passage structures to allow sturgeon to bypass dams and other river obstructions; (7) modeling of sturgeon populations; and (8) other studies.

To guide the overall efforts to preserve or restore gulf sturgeon, the USFWS and GSMFC (1995) established three main goals: (1) prevent the extinction of or irreversible damage to gulf sturgeon populations, (2) prevent the decline of existing gulf sturgeon populations and enhance and stabilize gulf sturgeon habitats, and (3) promote the restoration of gulf sturgeon populations to their former levels.

These actions along with the tasks spelled out in the Gulf Sturgeon Recovery/Management Plan (USFWS and GSMFC, 1995) are summarized in Appendix G. However, other questions must also be taken into consideration, such as "What is/are the best sampling technique(s) and how should the technique(s) be standardized across the range of gulf sturgeon habitat?""Will biologists have enough information to accurately determine population levels and determine which sturgeon habitats need protection?""Will the information be collected in the right way?" Sturgeon population data are needed for genetic studies to be conducted, and genetic data generated from the genetic studies can help with population modeling. The question of whether a standard exists to determine the threshold level for sturgeon genetic viability was raised. To obtain a gulf sturgeon population estimate, many researchers think it is best to collect three to five consecutive years of data from the same river basin; however, other researchers think it may be better to estimate gulf sturgeon populations by the "collective rodeo" approach, in which all gulf sturgeon biologists sample all gulf basins on a rotation basis. An example of the collective rodeo technique would be sampling the Apalachicola River Basin in the first year, the St. Andrew Bay Basin, the next etc., moving from east to west along gulf coast river drainages. However, weather problems could arise with floods and hurricanes, and if the collective rodeo approach is used, a whole river system could be missed as a result of unfavorable sampling conditions. To accurately determine the numbers present in small populations of sturgeon, a sampling program of relatively high intensity or of long duration is needed in order to reliably determine whether a population is increasing, decreasing, or remaining the same. A sturgeon population estimate cannot be accurate if population data estimates are available for widely spaced years because a large degree of variance can often be associated with widely spaced population estimates.

Following is a basin-by-basin account, from west (Louisiana) to east (Florida), summarizing current information on gulf sturgeon. The lettered sections refer to the basin, and the numbered sections under the account for each of 11 basins correspond to the 8 action items previously listed.

[1]Also see MSU, 2001.

A. ATCHAFALAYA RIVER

5. DETERMINING POPULATION LEVELS

Although only one gulf sturgeon has been captured in the Atchafalaya River system during the past 20 years, gulf sturgeon are known to be living there. To determine how many sturgeon are present and where they are living, researchers could track acoustically tagged sturgeon. Because few sturgeon are evident in this river system, not much time or energy should be spent on the recovery of gulf sturgeon populations here (B. Reed, LDWF, personal communication).

B. MISSISSIPPI RIVER

1. REDUCING INCIDENTAL TAKE

Gulf sturgeon are unlikely to be caught by commercial fishers in this basin.

8. OTHER STUDIES

Sonic tracking in the Mississippi River Basin is difficult because the high conductivity of the water produces a lot of background interference. Therefore, a receiver needs to be developed to distinguish sounds produced by sonic tags from background noise. Researchers funded by the U.S. Navy are developing receiver technology that will accomplish this task. Although different species of pelagic fish can be identified by the resonance of their swim bladders when targeted by sonar, gulf sturgeon rest on the bottom and are difficult to distinguish from rocks or other bottom debris.

C. LAKE PONTCHARTRAIN AND PEARL RIVER (MISSISSIPPI–LOUISIANA)

1. REDUCING INCIDENTAL TAKE

All gillnets, trammel nets, and other entangling nets are banned from this system, but hoop nets are allowed. Some parts of Lake Pontchartrain are closed to trawling. Some Lake Pontchartrain shrimp fishers provided incidental take data until the Gulf Sturgeon Recovery/Management Plan was published in 1995 (USFWS and GSMFC, 1995), but no independent studies are currently being conducted. The effects of shrimp trawling on incidental catch of sturgeon need to be examined. For example, mortality rates of sturgeon placed in a shrimp net and towed for one hour need to be compared with mortality rates of sturgeon towed in nets for two hours.

2. IDENTIFYING FRESHWATER AND MARINE HABITAT

Because gulf sturgeon of various year-classes have been collected in the Lake Pontchartrain and Pearl River system, habitats within the basin needs to be surveyed in order to determine where gulf sturgeon spawn. Also, the locations where gulf sturgeon in various life-history stages live, including over-summering habitat, need to be determined. Sturgeon occupy the marine habitat of Lake Pontchartrain during the late fall and winter months, so the ongoing winter study of sturgeon in the marine habitat of Lake Pontchartrain needs to be completed to determine the locations of sturgeon within the marine ecosystem.

3. PROTECTING HABITAT

To date, no known gulf sturgeon spawning areas have been identified or located in Louisiana. Also, no limestone outcroppings, which are characteristic spawning habitats for gulf sturgeon in other gulf drainages exist in Lake Pontchartrain drainages. River substrates in Louisiana consist of gravel, coarse sand, and mussel beds, but sand- and gravel-mining operations within the basin produce pits that could be suitable sturgeon spawning habitats. The urbanization of the north shore of Lake Pontchartrain has increased the level of nutrients in the basin, which in turn has lowered dissolved oxygen levels and degraded water quality. Eutrophication in the Lake Pontchartrain and Pearl River basins needs to be examined by analyzing USGS water-quality data for Louisiana basins and comparing this information with the water-quality requirements of gulf sturgeon. Also, two hydroelectric power plants have been proposed, which if built would entail groundwater withdrawal, affecting spring-fed creeks, and would introduce warm-water effluent to the river. All of these factors could affect gulf sturgeon populations and need study.

4. DETERMINING DIETARY REQUIREMENTS

The winter-feeding study needs to be completed. Researchers are conducting studies on benthic communities and sturgeon diets in Mississippi Sound (R. Heard, USM, Gulf Coast Research Laboratory, personal communication).

5. DETERMINING POPULATION LEVELS

Data on this basin are being collected by university, state, and federal researchers and need to be shared with gulf sturgeon researchers so that an estimate of the gulf sturgeon population in this basin can be made. A university, state, or federal agency needs to commit to gulf sturgeon research efforts in the Lake Pontchartrain and the Pearl River basin so a long-term funding source can be secured.

6. PROVIDING FISH PASSAGE

We need to determine whether sills, dams, and impoundments in the Lake Pontchartrain and Pearl River Basin should be removed to improve the sturgeon's upstream and downstream mobility. Sturgeon do not navigate locks or elevators well, and several states are working on projects to facilitate sturgeon movement around or remove these obstructions. For example, B. Kynard at the USGS Conte Fish Lab in Massachusetts has developed a laboratory model of a sturgeon passage structure that uses low-gradient spiral baffles and is building a full-sized prototype for testing, and the need for North Carolina's Cape Fear lock-and-dam project is currently being evaluated by biologists and may be removed in the future. A partnership between Mississippi and Louisiana biologists and USACOE in Vicksburg should be formed to obtain funding for gulf sturgeon passage research.

7. MODELING POPULATIONS

In 1996, age-structure data were collected for the Pearl River gulf sturgeon population. A population model can be developed from these data and then mortality rates can be applied to the model. The Waterways Experimental Station (WES) will complete the gulf sturgeon population model for the Pearl River sometime in 2001.

D. PASCAGOULA–LEAF–CHICKASAWHAY RIVERS (MISSISSIPPI)

1. REDUCING INCIDENTAL TAKE

Mississippi Sound is trawled extensively by shrimpers, which may affect gulf sturgeon distribution or abundance. There is also anecdotal evidence that incidental take of sturgeon occurs in shrimp fisheries in the Pascagoula-Leaf-Chickasawhay river system, and because gillnetting is allowed in specific areas of the Pascagoula system at certain times of the year, sturgeon could be accidentally captured. To see what effects are caused by prolonged entrapment in trawls, the National Marine Fisheries Service, as part of its research on turtle excluder devices (TEDs), could place sturgeon in nets and tow the nets for various lengths of time or observers could be placed on shrimp trawlers. J. Lee (NMFS, St. Petersburg) will be exploring the costs of both programs and will draft proposals for both a trawl-effects research program and an observer program. If there is significant bycatch of sturgeon in shrimp trawls, regulations on shrimpers could be increased. Additionally, researchers could compare the locations where tagged sturgeon occur with the locations of shrimp trawl records to see whether sturgeon habitat is being fished by shrimpers. R. Lukens (GSMFC) is exploring this option.

2. IDENTIFYING FRESHWATER AND MARINE HABITAT

In the Pascagoula River system, research on the freshwater and marine habitats of sturgeon is ongoing, although gulf sturgeon need to be sonically tagged and tracked for researchers to locate them in the Gulf of Mexico during the winter. When the study is completed, researchers will have a better idea of where gulf sturgeon over-summer and spawn in the Pascagoula River system and where in the Mississippi Sound and Gulf of Mexico they spend the winter. USM has received funding from the Shell Foundation, and Sea Grant funding is likely to continue; USM may also be able to get funding under Section 6 of the Clean Water Act to study sturgeon in the riverine parts of the system.

3. PROTECTING HABITAT

The Bouie River is the only known spawning site for gulf sturgeon in the Pascagoula River system. Additional sturgeon spawning locations in the Pascagoula River system will be identified in the near future.

Mining, water withdrawal, dredging, and urban development affect sturgeon habitat in the Pascagoula, Leaf, and Chickasawhay system. Operations of gravel mines during the past 80 years have affected sturgeon habitat in the Pascagoula River, but no new permits have been issued for gravel mining. Chevron withdraws water from the Pascagoula River during their power petroleum operations, which affects the water depths of sturgeon summer habitat. A pulp and paper mill imposes biological oxygen demand (BOD) on effluent water, but the levels of BOD are controlled. However, the conductivity and watercolor caused by the mill operations need to be improved. Both dredging of navigation channels on the lower portion of the Pascagoula River for barge traffic and the disposal of the dredged material affect sturgeon.

The Nature Conservancy recently purchased a tract of land in the lower Pascagoula basin bordering the Chickasawhay and Leaf rivers; this tract will form a conservation easement, and because it will be part of the Pascagoula Wildlife Management Area, it will be a well-protected summer resting area for sturgeon. However, other potential sturgeon spawning areas and areas upstream are probably not as well protected and need further protection from land use and urbanization. For example, the recent building of casinos in Biloxi has necessitated the filling-in of sand-and-mud-bottom habitats there, which could permanently affect nearshore habitat of Mississippi Sound. These nearshore habitats are thought to be important feeding grounds for gulf sturgeon, and destruction of these habitats could result in the loss of sturgeon winter-foraging habitat and the possible disruption of sturgeon migration patterns.

4. DETERMINING DIETARY REQUIREMENTS

R. Heard (USM, Ocean Springs) has taken benthic samples from locations where sturgeon have been tracked by telemetry, and these studies will be correlated with studies of food items in sturgeon stomach contents, which can help determine the locations in the bay or estuary where sturgeon feed. Lavage (stomach pumping) will be conducted on sturgeon entering the Pascagoula River in the spring. Also, radio or sonic tags will be applied to lavaged sturgeon, and they will be tracked to determine whether the lavage technique has adversely affected them in any way.

5. DETERMINING POPULATION LEVELS

Capture-mark-recapture population studies have been conducted in the gulf sturgeon summer holding areas of the Pascagoula River system. Gulf sturgeon population data have been collected for two years in the Pascagoula River, and the population is estimated to be about 200 summer-staging sturgeon. However, the summer samples were taken using gillnets, which collect primarily large adult sturgeon—few juvenile and subadult sturgeon are collected with this method. Because the size of the gillnet mesh biases the population estimate, the population structure estimated is based principally on large fish, so a more realistic age-structure analysis is needed for gulf sturgeon in all life-history stages in this system. A long-term funding commitment is needed to determine whether the sturgeon population is stable, increasing, or decreasing, and because female sturgeon do not mature till age 12, 10 more years of gulf sturgeon population data may be needed from the Pascagoula River system.

6. PROVIDING FISH PASSAGE
Rock piles located above spawning areas, such as at the Bouie River, could impede sturgeon migration during periods of low water flow. The Bouie River rock pile is not as big a problem as that posed by a dam or other barrier because, according to anecdotal accounts, sturgeon can pass over the rock pile during periods of high water flow.

A group in Hattiesburg, Mississippi, proposed that a low-head dam be constructed on the Bouie River to provide a future drinking-water supply. Locations previously suggested for building a dam on this river were all below the only known spawning site for gulf sturgeon in the Pascagoula System, which would have precluded gulf sturgeon from spawning, but the currently proposed dam site is located immediately above the sturgeon spawning site. In 2000, a Mississippi legislator proposed construction of a dam on Bluff Creek, a Pascagoula River tributary near Vancleave, Mississippi; Mississippi House Bill 68 died in committee but may be reintroduced again in 2001. Because gulf sturgeon use the lower reaches of Bluff Creek during certain times of the year, this dam could prevent sturgeon movement (D. Fruge, USFWS, Ocean Springs, Mississippi, personal communication).

7. MODELING POPULATIONS
Researchers are still in the early stages of gathering information, and they will evaluate sturgeon populations as more data become available. Researchers are also looking at the genetic structure of the sturgeon population and the number of sturgeon that contribute to reproduction and gene flow in the Pascagoula River as part of the population model.

E. ALABAMA RIVER/MOBILE (ALABAMA)
3. PROTECTING HABITAT
A study of the Alabama-Mobile River basin is currently being conducted to evaluate stream flow, fish passage, and fish species. The effects of thermal plumes on the Alabama River need to be investigated, because the apparent absence of gulf sturgeon in the system could be a result of the high temperatures of the effluent released from the Barry Steam Plant. According to C. Couret (USFWS, Daphne, Alabama, personal communication), the temperature of the plant's outfall, measured in August, was 32°–43°C from bank to bank and to 13 m deep. Effluent has been discharged from this plant since the 1970s and could have been acting as a thermal barrier for sturgeon. In August 2000, minimum surface water temperatures, measured 1.6 km upstream and 14.5 km downstream from the discharge site, were 35°C. Any living organism drifting in the thermal plume would be cooked in this warm water. (In the hatchery environment, 2- to 5-year-old gulf sturgeon will die at temperatures of 33°C (A. Brown, USFWS, Welaka NFH, personal communication). Proposed construction of gas pipelines from the Alabama coast to Tampa Bay may traverse sturgeon winter foraging habitat.

5. DETERMINING POPULATION LEVELS
In the Alabama River system, we need to determine whether gulf sturgeon are present. Only then can the recovery of sturgeon populations be addressed. Sturgeon could be located with the use of aquacultured sentinel fish that have been tagged and and tracked.

F. ESCAMBIA RIVER–YELLOW RIVER–BLACKWATER RIVER (FLORIDA)
1. REDUCING INCIDENTAL TAKE
Anecdotal reports suggest that sturgeon occur as bycatch in shrimp trawls in Pensacola Bay. According to F.S. 370.15, Santa Rosa Sound is closed to food shrimping. Other areas of Pensacola Bay have local laws regarding shrimp trawling and have certain seasons for shrimping.

2. IDENTIFYING FRESHWATER AND MARINE HABITATS
Researchers are studying the preferred freshwater habitats for gulf sturgeon in the Yellow and Escambia rivers. N. Craft (NW Aquatic Preserves, FDEP) is conducting sonic surveys of sturgeon in the river systems, and R. Heard, USM, Ocean Springs, is conducting surveys of benthic invertebrates in Pensacola Bay.

3. PROTECTING HABITAT
Six new water wells have been proposed for construction near Crestview, Florida, and water would be piped to southern Okaloosa County, where water levels in existing wells have been declining and wells are experiencing saltwater intrusion. These new wells could affect the Floridan Aquifer as well as the surface aquifers that feed springs along the Yellow River. Also, a dam on the Yellow River has been proposed to create a freshwater reservoir in Okaloosa County (Stewart, 2000). However, five potential sturgeon spawning sites (with characteristic limestone outcroppings) would be af-

fected by the dam; one site is below the proposed dam site, two sites are at the proposed dam location, and two sites are located above the proposed dam (N. Craft, NW Aquatic Preserves, personal communication).

Deadhead log removal and sedimentation from dirt roads are continuing to destroy riverine habitat and need to be limited to protect sturgeon habitat.

4. DETERMINING DIETARY REQUIREMENTS
R. Heard and J. McLelland (USM, Ocean Springs) are planning to collect and identify benthic invertebrates from the sediment and from sturgeon stomach contents. Gastric lavage techniques were demonstrated at a mini-workshop held at the University of Florida's Institute of Food and Agricultural Sciences facility in Gainesville in June 2001.

5. DETERMINING POPULATION LEVELS
N. Craft, NW Aquatic Preserves, FDEP, is conducting tagging and movement studies of gulf sturgeon in the Yellow and Escambia rivers. No population estimates have yet been determined for these river systems, and data on the sturgeon's genetic and age structures need to be collected for these river systems.

6. PROVIDING FISH PASSAGE
A group called Citizens for Water Conservation in Okaloosa County (Stewart, 2000) has proposed construction of a 10,000-acre reservoir on the Yellow River near Milligan, Florida, as an alternative to drilling additional water wells. If this reservoir is built, fish-passage structures will have to be incorporated in the dam's design.

7. MODELING POPULATIONS
Sturgeon population models cannot be constructed for the Pensacola Bay system until population levels are determined for the Yellow, Escambia, and Blackwater river systems.

G. CHOCTAWHATCHEE RIVER (FLORIDA)

1. REDUCING INCIDENTAL TAKE
Only two small areas are closed to food shrimp trawling in Choctawhatchee Bay, and there is anecdotal evidence that incidental take of gulf sturgeon by shrimpers is occurring in the bay. To determine whether commercial shrimping is affecting sturgeon, the locations of the sturgeon's winter foraging habitats in Choctawhatchee Bay should be compared to the locations of areas in the bay where shrimping occurs (perhaps by using GIS technology). Also, the results from the NMFS bycatch study and shrimp trawl trip-ticket information need to be evaluated to determine whether shrimpers are fishing in areas occupied by gulf sturgeon and whether further regulation of the fishery is warranted.

2. FRESHWATER AND MARINE HABITAT STUDIES ARE ONGOING
D. Fox and J. Hightower at North Carolina State University have characterized the freshwater habitats, including spawning habitat used by gulf sturgeon in the Choctawhatchee River in summer and have determined which marine and estuarine habitats are used in winter by adult gulf sturgeon in Choctawhatchee Bay.

3. PROTECTING HABITAT
Sedimentation from dirt roads continues to affect sturgeon river habitat; 70% of sediments in the Choctawhatchee River come from dirt roads. With funding from the Choctawhatchee, Pea, and Yellow River Water Management Authority the Poly Engineering Company in Dothan, Alabama, prepared a manual and a video to train engineers on how to grade roads so that the amount of sediments entering the river are reduced. Training sessions for road construction engineers have been held in Alabama.

4. DETERMINING DIETARY REQUIREMENTS
R. Heard and J. McLelland (USM, Ocean Springs) are analyzing the distribution of benthic organisms in Choctawhatchee Bay, and D. Murie and D. Parkyn (University of Florida, Gainesville) have developed a lavage technique that is being used to extract stomach contents from sturgeon. This will allow researchers to determine where in the bay the sturgeon's prey live.

5. DETERMINING POPULATION LEVELS
Researchers with the USFWS, Panama City, used the "out-migration method" to collect data for sturgeon population estimates for the Choctawhatchee River. In this technique, gillnets are anchored at the mouth of the river during October to November, when sturgeon are heading down to the bay. From these data, the USFWS researchers estimated that there were 3,000 sturgeon in the Choctawhatchee River in 1999 and 1,815 sturgeon in 2000. It is essential to continue gathering data for the Choctawhatchee system because only two years of data have been collected thus far.

6. PROVIDING FISH PASSAGE
A private dam on the Pea River blocks access by sturgeon to 6.4 to 8 km of spawning habitat. The United States Army Corps of Engineers last examined this dam in March 2000, and the status of discussions between the Corps and the dam's owner about its removal need to be monitored.

7. MODELING POPULATIONS
No sturgeon population models have been constructed for the Choctawhatchee system, but the model being developed by M. Allen (University of Florida, Gainesville) for sturgeon in the Suwannee River system could be applied to the Choctawhatchee population.

H. ECONFINA CREEK (FLORIDA)
2. IDENTIFYING FRESHWATER AND MARINE HABITAT
Econfina Creek may have been important gulf sturgeon habitat in the past. However, in 1962, a dam was constructed above North Bay, forming Deer Point Lake and preventing anadromous fish migration. St. Andrew Bay may provide winter habitat for gulf sturgeon because it is deep and estuarine.

I. APALACHICOLA RIVER (FLORIDA)
1. REDUCING INCIDENTAL TAKE
Wooley and Crateau (1985) documented that sturgeon have been caught by shrimpers in Apalachicola Bay, and anecdotal evidence suggests that this incidental take by shrimpers still occurs. Trip ticket information needs to be analyzed to determine whether a correlation exists between the areas where sturgeon occur in Apalachicola Bay and the areas there where shrimp trawlers fish. Florida Statute 68B-31.018 has closed 10,522 hectares of Apalachicola Bay and St. Vincent Sound and 526 hectares acres of St. George Sound to shrimping. The same statute also provides for seasonal closures of 2,630 hectares in Apalachicola Bay and St. Vincent Sound from March 1 to May 31 and 3,480 hectares acres in St. George Sound from September 15 to December 31.

2. IDENTIFYING FRESHWATER AND MARINE HABITATS
Six potential sturgeon spawning habitats with limestone outcroppings and gravel substrate have been identified in the Apalachicola River system, and surveys are being conducted to determine whether more spawning sites exist (Appendix C). The USFWS and the Georgia Department of Natural Resources are conducting a study to locate sturgeon habitat and spawning areas on the Flint River, which extends for 112.6 km above the JWLD, and the Chattahoochee River, which extends for 48.3 km above the JWLD.

3. PROTECTING HABITAT
The Apalachicola-Chattahoochee-Flint Compact prohibits commercial barge traffic on these rivers during certain times of the year to allow sturgeon to migrate unimpeded, but biologists are uncertain whether these windows protect juvenile sturgeon. Because sturgeon congregate at the base of the JWLD, spawning habitat could be created there by the addition of gravel of appropriate size (2–10 cm). Many km of potential spawning habitat exist on the Flint River, and larval sturgeon have been found below the JWLD. The river is dredged frequently for barge traffic, and Florida has recently begun requiring permits for disposal of this dredged river material. Twenty dredge spoil sites along the Apalachicola River in Florida will be restored to their original condition over the next five years. Springs and thermal refuges in the river are important for sturgeon habitat and need to be protected.

4. DETERMINING DIETARY REQUIREMENTS
The stomach-lavage technique can be used to extract sturgeon stomach contents, and the organisms found can be used by researchers to determine where and on what these sturgeon have been feeding.

5. DETERMINING POPULATION LEVELS
The USFWS has conducted sturgeon population estimates in the Apalachicola River system for the past two years. Approximately 300 sturgeon occupy the system. Although the USFWS has collected 75 sturgeon in the Brothers River, no population estimates in this river have been made.

6. PROVIDING FISH PASSAGE
The use of the Apalachicola, Chattahoochee, and Flint rivers for commercial boat and barge traffic has been the prime rationale for the authorization of the JWLD. If this rationale is abandoned, as now seems possible, then incorporation of fish-passage structures into the dam's structure, or even the dam's removal, becomes more feasible.

7. MODELING OF POPULATIONS
A sturgeon population model needs to be constructed for this river system.

J. OCHLOCKONEE RIVER (FLORIDA)
1. REDUCING INCIDENTAL TAKE
Florida Statute 68B-31.018 closes 20,072 hectares in the Ochlockonee Basin year round to shrimp trawling, but incidental take of sturgeon in shrimp trawls probably has and may continue to occur.

2. IDENTIFYING FRESHWATER AND MARINE HABITATS
In July 2000, commercial fishers led researchers to areas where sturgeon had been netted. Six sturgeon ranging in weight from 3.6 to 18.1 kg and belonging to multiple year-classes were netted 8–12.9 km upstream from the river mouth. In the past, commercial fishers caught

sturgeon up to 64.4 km (halfway) up the Ochlockonee River. F. Parauka, USFWS, Panama City is identifying and documenting spawning sites on this river system (Appendix C). A telemetry study is needed to further document sturgeon habitat use.

3. PROTECTING HABITATS
More studies are needed on this river system to determine which habitats to protect.

4. DETERMINING DIETARY REQUIREMENTS
No data currently exist regarding the diet of sturgeon in the Ochlockonee River.

5. DETERMINING POPULATION LEVELS
Genetic, age-structure, and population-trend studies are needed before sturgeon population levels in the Ochlockonee River can be determined.

6. PROVIDING FISH PASSAGE
Fish passage is not a documented problem in the Ochlockonee river system.

7. MODELING OF POPULATIONS
This will be the last study conducted on this river.

K. SUWANNEE RIVER (FLORIDA)
1. REDUCING INCIDENTAL TAKE
Collisions between sturgeon and boats occur frequently, especially on long holiday weekends, and although several "no-wake" zones already exist on the Suwannee River for manatees, more are needed to protect sturgeon. Anecdotal evidence suggests that sturgeon are sighted during the night, when fishers who are gigging for catfish may be snagging sturgeon. Florida Statute 68B-31.017 closed 191,300 hectares in the Big Bend area year-round to shrimp trawling activities.

2. IDENTIFYING FRESHWATER AND MARINE HABITS
The Suwannee River sturgeon population has been the most extensively studied gulf sturgeon population, so more is known about sturgeon on this river system than about gulf sturgeon on any other gulf river system. More sturgeon marine migration studies are needed—a satellite pop-off tag project will be conducted (Appendix C), and sturgeon will be sonically tagged and tracked (Appendix C).

3. PROTECTING HABITAT
The Suwannee River Water Management District manages land and has tightened regulations on construction along the Suwannee River, but proposed dredging of East and West passes could affect sturgeon habitat.

4. DETERMINING DIETARY REQUIREMENTS
Several researchers have documented diets for the Suwannee River gulf sturgeon population. D. Murie and D. Parkyn, University of Florida, Gainesville, are conducting more studies (Appendix C).

5. DETERMINING POPULATION LEVELS
To estimate the number of sturgeon in the Suwannee River, the University of Florida has used the "in-migration method," in which gillnets are anchored at the river mouth from February to March to capture sturgeon as they begin their migration into the river. The mean population size from 1987 to 1996 was estimated to be 3,152 fish (Chapman et al., 1997). Another estimation technique, the "out-migration" method, in which gillnets are put at the river mouth from October to November when sturgeon are moving out of the river; this method has been used by K. Sulak, (USGS, Biological Resources Division, Gainesville) and other USGS researchers. The most recent "out-migration" sturgeon population estimate is 7,650 fish (Sulak and Clugston, 1999). Sturgeon aquaculture researchers continue to remove broodstock from the Suwannee River, but researchers and managers are uncertain of how broodstock removal will affect the native sturgeon population. Also, researchers and managers are uncertain about whether springtime netting of sturgeon affects the Suwannee River sturgeon population. A minimum size and number of spawning sturgeon for broodstock collection needs to be established so the Suwannee River sturgeon population can remain viable.

6. PROVIDING FISH PASSAGE
No dams exist on this river, so fish passage is not an issue.

7. MODELING POPULATIONS
M. Allen, University of Florida, Gainesville, is constructing a population model for Suwannee River gulf sturgeon (Appendices B, C). The model will be produced in 2001 and may be useful if applied to gulf sturgeon populations in other river systems.

8. OTHER RESEARCH
Funding for gulf sturgeon research could be available from the USFWS, Saltonstall-Kennedy Grants, and Coastal Zone Management. The environmental tolerances of gulf sturgeon in the four juvenile life stages (egg to age one, larvae, postlarvae, and YOY) need to be determined and summarized. A protocol for sam-

pling gulf sturgeon in the early-life-history stages will be developed.

MANAGEMENT PLANS

The most extensive gulf sturgeon plan will be the State of Florida Gulf Sturgeon Conservation Plan. Management plans are also being developed for the Mobile Basin, Alabama Basin, and the Pascagoula and Pearl rivers.

If $50,000 were available for studies in each basin, the most important studies would be these:

- Lake Pontchartrain and Pearl River—winter habitat;
- Pascagoula River—genetics, movement patterns, and marine habitats;
- Atchafalaya and Black rivers—telemetry and genetics;
- Alabama River—telemetry and genetics;
- Escambia,Yellow, and Blackwater rivers—population estimates;
- Choctawhatchee River—early life history (especially YOY) and habitat use;
- Apalachicola River—egg collection and fish passage;
- Ochlockonee River—telemetry; and
- Suwannee River—marine habitat studies.

The Progress Report Table (Appendix G) and the notes in this appendix are also summarized in MSU (2001). An annual meeting will be held every September to update priorities for gulf sturgeon research.

APPENDIX F

Protocol for Sampling Gulf Sturgeon Tissue

The following protocol for collecting fin clips is currently used by the Ross Laboratory, University of Southern Mississippi, and will be used by gulf sturgeon researchers.

Remove one square inch of the pectoral fin with a sharp pair of scissors (the pectoral fin is not well vascularized, so it does not bleed much and the fin clipping mostly regenerates within a year). Place the fin clipping in an envelope on ice for transport; store in a freezer upon return to the laboratory. As an alternative, a fin clipping can be placed in a 2-ml vial of tissue-preservation buffer and shaken until the buffer covers the fin clip. With this method, there is no need to refrigerate or freeze the sample. Along with the sample, include any data regarding the specimen (*e.g.,* length, sex [if known], capture location, date of capture, and any tag number). Upon request, researchers can get vials and buffer solution from the Ross Laboratory. A tissue bank will be developed from these specimens.

Send fin clips from Florida gulf coast drainages to
Dr. Michael D. Tringali
Florida Marine Research Institute
Florida Fish and Wildlife Conservation Commission
100 8th Avenue SE
St. Petersburg, FL 33701
Phone: (727)896-8626
E-mail: Mike.Tringali@fwc.state.fl.us

Send fin clips from other gulf coast drainages to
Dr. Brian Kreiser
Department of Biological Sciences
Box 5018
University of Southern Mississippi
Hattiesburg, MS 39406-5018
Phone: (601)266-6556
E-mail: Brian.Kreiser@usm.edu

ADDITIONAL NOTES

The University of Alabama could also be used as a genetic repository or genetic bank for sturgeon samples, and C. Woodley at the NMFS Laboratory in Charleston, South Carolina, has organized a genetics bank for sturgeon samples. So far, only Atlantic and shortnose sturgeon samples have been obtained, but the bank could be expanded to include gulf sturgeon samples (M. Collins, SCDNR, personal communication).

The sex of sturgeon can be determined by taking blood samples from the caudal vein below the anal fin. Protocols need to be sent out and laboratory needs have to be checked to determine if this is a normal medical procedure. Perhaps USFWS Warm Springs, Georgia, or USFWS Bears Bluff, South Carolina, could help with sexing sturgeon with blood samples.

APPENDIX G

Progress Report—Gulf Sturgeon Recovery Implementation 1995–2000
(Acronyms identified in Appendix H)

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
1	1.3.1	Develop and implement standardized population sampling and monitoring techniques	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently	1) Standardized sampling design and operating procedures developed	USGS, BRD, Raleigh, North Carolina	USFWS, USGS	1) Develop proposal to implement 2) Conduct research to improve sampling techniques
				2) Draft report of design completed	USGS, BRD, Raleigh, North Carolina	USFWS, USGS	
				3) Standardize fin-ray collection and aging techniques	USM, Hattiesburg, Mississippi; FWC, St. Petersburg, Florida	——	3) Verify correct aging techniques
1	2.5.3	Develop and implement a regulatory framework to eliminate accidental and intentional introductions of non-indigenous stock or other sturgeon species	Some of this effort will be dependent on the outcome of 2.5.1	1) Florida aquaculture requirements for BMPs, 1997	Florida Legislature	——	1) Active participation in Florida request
				2) CITES prohibitions starting April 1, 1998	CITES	——	2) Critical review of BMPs for aquaculture
				3) Request for state-federal partnership to address aquaculture in Florida formation of FSPWG	Florida House Committee on Agriculture	——	3) Writing, implementation, and adoption of BMPs
				4) Sturgeon Aquaculture Risk Assessment Workshop held April 6–7, 2000	FDEP/FWC (BMPs) will be developed as a result of workshop recommendations	FWC, FDACS	
				5) Develop and implement an imperiled-fishes management-recovery plan	Southeast Imperiled Fishes Group	USFWS	
1	2.1.2	Reduce or eliminate incidental mortality	Need funding for fish excluder devices and development of sampling protocols	1) Developed guidelines to reduce incidental mortality during gillnet sampling	USFWS, Panama City, Florida	USFWS	1) Investigate potential incidental take in Lake Pontchartrain, Louisiana

				2) Species considered in fish excluder device evaluation	Gulf States Marine Fisheries Commission	GSMFC	2) Investigate incidental take by Gulf of Mexico shrimp fleet
				3) Florida net ban constitutional amendment	Citizens of Florida, FWC Law Enforcement	Florida General Revenue Funding	
1	2.4.5	Restore the benefits of natural riverine habitats	Work funded under existing programs Actual restoration costs undetermined	1) Identifying opportunities for restoring natural flow regimes in ACF and ACT Compacts	USFWS, Panama City, Florida, and USFWS, Daphne, Alabama	USACOE, USFWS	1) Continued support for ACT and ACF Compact negotiations
				2) Identifying partnership opportunities for riparian restoration in northeast gulf watersheds	USFWS, Panama City, Florida, and USACOE, Mobile, Alabama	USFWS, NRCS, and USACOE	2) Partnership support for projects 3) Restore natural water flows
					FWC, St. Petersburg, FDEP, Division of State Lands, and FNAI	Multiple Sources	4) Acquire lands in watersheds to protect habitat
1	2.3.1	Use existing authorities to protect habitat and where inadequate, recommend new incentives, laws, and regulations	Section 7 consultation conducted with existing program funds	1) Numerous Section 7 formal and informal consultations	USFWS and other federal agencies	——	Review habitat protection inadequacies
				2) Acquisition of riparian lands	NWFWMD, SWMD	NWFWMD, SWMD	
2	2.1.1	Increase effectiveness and enforcement of state and federal take prohibitions	1) Section 7 consultations will be conducted under existing programs	1) Forensic techniques under development to identify caviar by species	USFWS, Ashland, Oregon, and USFWS, Shepherdstown, West Virginia	USFWS	Evaluate need for increased law enforcement presence
			2) Additional monitoring or law enforcement personnel may be necessary	2) Forensic techniques to differentiate wild from farm-raised gulf sturgeon	FDACS, Tallahassee, Florida	FWC	

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
2	1.1.1	Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently	1) Documented 2 gulf sturgeon spawning sites and characterized habitat in the Suwannee River	USGS, BRD, Gainesville, Florida	USFWS, USGS	1) Surveys for gulf sturgeon feeding and developmental habitats in Florida Panhandle rivers
				2) Documented 6 spawning sites and characterized habitat in the Choctawhatchee River, Florida	USGS, BRD, Raleigh, North Carolina	USFWS, USGS	2) Surveys for gulf sturgeon habitats in Atchafalaya and Mississippi rivers and Lake Pontchartrain-Pearl River basin; Alabama and Mobile rivers
				3) Documented 1 spawning site and characterized habitat in the Bouie River, Mississippi	USM, Hattiesburg, Mississippi; MMNS, Jackson, Mississippi	USFWS	
				4) Document sturgeon spawning and characterize habitat in Yellow and Escambia rivers	FDEP, NW Aquatic Preserves Milton, Florida; USFWS & Eglin AFB provided equipment & assistance	FWC, St. Petersburg, Florida	3) Surveys to determine if any sturgeon present in Tchefuncte, Bogue Chitto, Tickfaw, and Tangipahoa rivers (Louisiana)
				5) Documented 6 gulf sturgeon spawning sites and characterized habitat in Apalachicola River, Florida	USFWS, Panama City, Florida	USFWS, Panama City, Florida	4) Surveys in other rivers in Mississippi?
				6) Document potential sturgeon spawning sites in Florida Panhandle rivers	USFWS, Panama City, Florida	FWC, St. Petersburg, Florida	5) Surveys in other rivers in Florida?
				7) Document gulf sturgeon spawning sites in the Pearl River, Louisiana	LDWF, Slidell, Louisiana	LDWF & USACOE	

2	1.1.2	Characterize riverine, estuarine, and neritic areas that provide essential habitat	Tasks 1.1.1 and 1.1.2 can be conducted concurrently	1) Documented and characterized gulf sturgeon freshwater habitat use in the Suwannee River, Florida	USGS, BRD, Gainesville, Florida; CCC, Gainesville, Florida	USGS, USFWS, Phipps Foundation	1) More detailed evaluations of microhabitats in all Florida Panhandle rivers
				2) Documented and characterized gulf sturgeon freshwater habitat use in the Choctawhatchee River, Florida	USGS, BRD, Raleigh, North Carolina	USFWS, USGS	2) More detailed evaluations of marine habitats in Florida, Louisiana, Alabama, and Mississippi
				3) Characterized gulf sturgeon summer habitat use in the Choctawhatchee River, Florida	USFWS, Panama City, Florida	USFWS	3) Need information on early-life-history stages, especially from egg to year 1
				4) Documented gulf sturgeon habitat preference and migratory patterns in Lake Pontchartrain and the lower Pearl River, Louisiana and Mississippi	USACOE, Vicksburg, Mississippi; LDWF	USACOE & LDWF	4) Need spawning locations and water-quality info for Atchafalaya River (Louisiana), Mississippi River, Pontchartrain & Pearl rivers (Louisiana & Mississippi), and Alabama & Mobile rivers
				5) Document gulf sturgeon habitats and migratory patterns in Pascagoula Bay, Pascagoula River, and Mississippi Sound	USM, Hattiesburg, Mississippi; MMNS, Jackson, Mississippi	USFWS, Mississippi-Alabama Sea Grant	5) Document marine habitat use in Apalachicola Bay, St. Joseph Bay, St. Andrew Bay, and Gulf of Mexico
				6) Document sturgeon marine habitat use in NE Gulf of Mexico	USGS, BRD, Gainesville, Florida	USGS, NMFS, and USFWS	6) Document use in Gulf of Mexico and bays into which Louisiana, Mississippi, and Alabama river systems empty
				7) Document adult and subadult sturgeon marine & estuarine habitat use in Choctawhatchee Bay & Gulf of Mexico	USGS, BRD, Raleigh, North Carolina; USFWS, Panama City, Florida	USGS, NMFS, and USFWS	

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
				8) Document sturgeon marine habitat use in Pensacola Bay, Florida	FDEP, Milton, Florida; USFWS, Panama City, Florida	FDEP, USFWS, and Eglin AFB	
				9) Document sturgeon habitat use in Lake Pontchartrain	LDWF and USFWS	LDWF and USFWS	
				10) Document benthic food availability associated with sturgeon habitat use in Choctawhatchee Bay, Florida	USM, Ocean Springs, Mississippi	FWC and USFWS	
				11) Document sturgeon movement and habitat use in Apalachicola Bay, Florida	USFWS, Panama City, Florida; FWC/FMRI, East Point, Florida	USFWS and USACOE	
2	1.2	Conduct life history studies on the biological and ecological requirements of little-known or inadequately sampled life stages	Tasks 1.1.1, 1.1.2, and 1.2 can be conducted concurrently	1) Data collected during habitat studies of Choctawhatchee River	USGS and NCSU, Raleigh, North Carolina	USFWS, USGS	1) Larval and post-larval movement and distribution
				2) Environmental tolerances of oxygen demand, temperature, current velocity, and other environmental parameters	UF, IFAS, Gainesville, Florida	FWC, St. Petersburg, Florida	2) Diets of sturgeon in estuaries and/or marine habitats 3) Distribution, relative abundance, and age structure of sturgeon throughout the range
				3) Develop nonlethal methods to examine stomach contents	UF, IFAS, Gainesville, Florida (Suwannee River)	FWC, St. Petersburg, Florida	
				4) Study sturgeon diets in estuaries and/or marine habitats	UF, IFAS, Gainesville, Florida (Suwannee River); USM, Ocean Springs, Mississippi (Choctawhatchee Bay)	FWC, St. Petersburg, Florida	4) Laboratory studies on habitat requirements and tolerances of larval, juvenile, subadult, and adult sturgeon

				5) Study sturgeon diets in estuaries and/or marine habitats	USM, Hattiesburg; MMNS, Jackson (Mississippi Sound and northern Gulf of Mexico)	Mississippi-Alabama Sea Grant, Shell Foundation for Marine Research	5) Develop ultrasonic techniques to document estuarine and marine habitat use
				6) Describe early life history of gulf sturgeon in the Suwannee River, Florida	USGS, BRD, Gainesville, Florida	USGS and FWC	
2	2.2.1	Identify potentially harmful chemical contaminants and water quality and quantity changes associated with surface water restrictions	Cost and time to complete year-2 efforts will be dependent on data collected in year 1	1) Alabama River thermal plumes 2) Crestview, Florida, dams and wells on Yellow River	USFWS, Daphne, Alabama ?	—— ——	Compile 305(b) reports by watersheds and identify data gaps
2	2.2.2	Identify and eliminate potentially harmful point and nonpoint sources of chemical contaminants		1) EPA programs 2) NRCS programs	EPA NRCS	EPA NRCS	Priorities for funding to gulf sturgeon watersheds
2	2.4.6	Seek optimal consistency between purposes of federal & state authorized reservoirs, flood control, navigation, & hydropower projects & federal & state mandated restorations of fish populations	Most agency-related work funded under existing programs	1) Being evaluated in ACF and ACT Compacts	USFWS, Panama City, Florida; USFWS, Daphne, Alabama, and USACOE	USACOE and USFWS	1) Incorporation of feasible recommendations in reservoir control manuals 2) Review operations in other basins

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
2	2.4.1	Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats		1) Fish Passage Workshop held in Wilmington, North Carolina	USACOE, Wilmington, North Carolina, March 2000	——	1) Evaluate important upstream habitat types
				2) Meetings with USACOE to discuss alternate fish passage around dams and obstructions	USACOE, Mobile, Alabama, March 1999; USACOE, Jacksonville, Florida, July 2000	——	2) Identify federal and nonfederal permitted dams
				3) Determine if dam on Pea River branch of Choctawhatchee River in Alabama can be removed or if there are alternate solutions for fish passage	——	——	3) Investigate ways of mitigating impacts on gulf sturgeon
				4) Evaluate passages for Bogue Chitto and Pools Bluff, Louisiana	——		
				5) Sturgeon fish passage study, JWLD Apalachicola River, Florida	USFWS, Panama City, Florida; GDNR, Albany, Georgia	USFWS and GDNR	
2	2.4.4	Identify potential modifications to specific navigation projects to minimize impacts that alter riverine habitats or modify thermal or substrate characteristics of those habitats	1) Some funding under existing programs	1) Evaluated for Pearl River consultation	USFWS, Vicksburg, Mississippi, and USACOE	USACOE and USFWS	Evaluate all gulf sturgeon life-history stages for other rivers
			2) Project costs undetermined and may require Congressional authorization & non-federal sponsor	2) Being evaluated in ACF and ACT Compacts	USFWS, Panama City, Florida; USFWS, Daphne, Alabama, and USACOE	USACOE and USFWS	
2	4.3	Implement projects or actions that will achieve recovery plan objectives	Individual project funding identification elsewhere in schedule	1) Develop a Florida conservation plan for gulf sturgeon	FWC, St. Petersburg, Florida	FWC	Overview of project opportunities and coordination with partners
				2) TNC Plans for Pearl & Pascagoula rivers	TNC	TNC	

				3) Alabama & Mobile Plans 4) Partners position with USFWS, Panama City, to address habitat restoration	State of Alabama? USFWS, Panama City, Florida	—— USFWS	
2	4.2	Seek funding for gulf sturgeon recovery activities	Funded under existing programs	1) Annual budget requests 2) UF workshop on aquaculture research funding needs 3) FWC contracts (1999–2000; 2000–2001)	State and federal agencies Florida and California Sea Grant FWC, St. Petersburg, Florida		1) Develop new multiyear funding needs assessment 2) Yearly regional meetings with representatives from Florida, Alabama, Mississippi, and Louisiana
2	2.2.4	Identify and eliminate known and potential impacts to water quantity and quality associated with existing and proposed developments, agricultural uses, and water diversions in management units	Amount of effort will be determined by outcome of task 2.2.1	1) NPDES reviews 2) Water quality criteria review 3) NRCS Programs 4) Developed dirt-road grading standard operating procedures	—— —— —— Choctawhatchee, Pea, and Yellow Rivers Water Management Authority	USFWS NGOs in 8 Alabama counties	1) Improve water quality 2) Assess effect of water quantity and quality on habitat 3) Assess effect of increased sediment loads and deadhead log removal on habitat
2	2.2.5	Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows	Mostly funded under the Tri-state Compact Study—Alabama, Georgia, and Florida	1) To be evaluated in ACF and ACT Compacts	USFWS, Panama City, Florida, and Daphne, Alabama, and USACOE	USACOE and USFWS	Address any groundwater concerns of other basins with gulf sturgeon populations

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
3	2.5.1	Evaluate the need to stock hatchery-produced gulf sturgeon considering habitat suitability and current population status	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently	1) Stocking strategy being evaluated based on genetic management units	USFWS, Panama City, Florida	USFWS	1) Integrate stocking strategy with population models
				2) State of Florida Gulf Sturgeon Conservation Plan	FWC, St. Petersburg, Florida	FWC, St. Petersburg, Florida	2) Workshop on sturgeon stock enhancement
				3) Hillsborough River Project to evaluate sturgeon habitat use in perturbed systems	FWC, St. Petersburg; Walt Disney Foundation, Orlando; MML, Sarasota; and HRGTF, Tampa, Florida	FWC, St. Petersburg, Florida	3) Florida state and federal habitat restoration programs
3	1.5.1	Conduct a gulf-wide genetic assessment to determine geographically distinct sturgeon management units	Majority of samples and analyses completed 1995 Will continue to completion	1) Completed a gulf-wide genetic assessment	USFWS, Panama City, Florida; New York University of Medicine, Tuxedo, New York; USM, Hattiesburg, Mississippi; UF, Gainesville, Florida; LDWF, MDWFP, USGS, Gainesville, Florida	USFWS and others	1) Mobile River system 2) Genetic tissue bank, University of Alabama? 3) Develop tissue-collection protocol
				2) Develop fin-clipping collection protocol	FWC, St. Petersburg; USM, Hattiesburg, Mississippi	—	
				3) Intradrainage population structure for Pascagoula River	USM, Hattiesburg, Mississippi; MMNS, Jackson, Mississippi	—	
				4) Develop tissue protocol	USM, Hattiesburg, Mississippi; MMNS, Jackson, Mississippi	—	

3	2.2.3	Assess selected contaminant levels in gulf sturgeon from management units	Study on adult fish across FL Panhandle completed 1994. Study on juvenile fish, Suwannee River completed 1995	1) Completed evaluation of Suwannee River juvenile sturgeon 2) One sample taken from Choctawhatchee River population	USGS, Gainesville, Florida USFWS, Panama City, Florida	USGS and FWC USFWS	1) Tissue analysis from remaining management units 2) Define bio-accumulation of contaminants in river systems by using surrogate species
3	1.3.2	Develop population models		1) Population model for Suwannee River under development 2) Population model for Pearl River under development	UF, IFAS, Gainesville, Florida WES, Vicksburg, Mississippi	FWC, St. Petersburg, Florida USACOE	1) Develop population viability proposal based on recommendations 2) Predict recovery potential by management units 3) Evaluate broodstock removal impacts
3	4.1	Designate and fund a gulf sturgeon recovery lead office	Majority of funding provided under other recovery actions	1) Panama City Field Office designated as federal recovery lead 2) FWC, St. Petersburg designated as State of Florida lead	USFWS, Atlanta, Georgia FWC, Tallahassee, Florida	— —	1) Continue funding support from Endangered Species programs 2) Clarify federal lead role with NMFS
3	1.4.1	Continue culture of gulf sturgeon		Develop culture techniques for gulf sturgeon	UF, IFAS, Gainesville, Florida USFWS, Welaka NFH, Florida; Warm Springs NFH, Georgia	NOAA, SK USFWS	Address data gaps (reproductive staging, broodstock holding and handling, hormone calculations, etc.)

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
3	2.2.6	Conduct studies to determine the effects of known chemical contaminants in water from management units on gulf sturgeon or a surrogate species	WNFH & NBS may provide specimens for the studies	Depends on concerns identified in 2.2.1			Bioassay work
3	2.4.3	Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation	Some funding under existing programs Project costs undetermined May require Congressional authority & non-federal sponsor				Dependent upon results from 2.4.4 and 2.4.6
3	2.3.2	Identify, protect, and/or acquire appropriate land or aquatic habitats on an ecosystem approach	ID conducted with other studies. Land acquisition & water rights costs undeterminable	1) Evaluation of northeast gulf watersheds underway	USFWS, Panama City, Florida	USFWS	1) Complete eco-system evaluation
				2) Develop State of Florida Sturgeon Conservation Plan	FWC, St. Petersburg, Florida	FWC	2) Initiate similar evaluations in other watersheds
				3) Alabama and Mobile Plans	USACOE?	——	3) Acquire lands in watersheds to protect juveniles, subadult, adult, and spawning sturgeon habitat throughout the species' range
				4) Pascagoula Wildlife Area and sections of lower Leaf River	TNC, Mississippi	TNC	
				5) TNC Plans Pascagoula and Pearl rivers	TNC, Mississippi	TNC	

3	2.4.2	Evaluate, design, and provide means for gulf sturgeon to bypass migration restrictions to essential habitats	USFWS & NMFS funded under existing programs. Studies conducted or infrastructure funded by USACOE & FERC. May require Congressional authorization & nonfederal sponsor				Review existing bypass structures and make recommendations for structures for sturgeon
3	3.1	Coordinate research and recovery actions	1) Funding for biennial workshops 2) Collect data to re-initiate directory of gulf sturgeon research activities 4) Collect data to re-initiate directory of gulf sturgeon research and activities	1) 1995 AFS session 2) 1997 USFWS workshop 3) 1998 sturgeon management workshop 4) 1998 AFS workshop 5) 2000 AFS workshop 6) 2000 gulf sturgeon workshop	AFS USFWS, Warm Springs FTC, Georgia USFWS AFS AFS USFWS, FWC, USM, Hattiesburg, Mississippi, and MSU, Stennis, Mississippi	—— USFWS —— —— —— ——	
3	2.5.2	Develop policy and guidelines for hatchery and culture operations related to stocking	Conducting this effort will be dependent on the outcome of 2.5.1	BMPs developed by FDACS through Sturgeon Aquaculture Risk Assessment Workshop	FDACS, Division of Aquaculture	FWC, St. Petersburg, Florida	1) Determine policy and guideline needs 2) Review suitability of existing BMPs
3	3.2	Develop an effective communication program or network to obtain & disseminate information on recovery actions & research results	Funding for producing and distributing quarterly newsletters	Gulf sturgeon intranet site initiated March 2000	FWC, St. Petersburg, Florida		Central location for educational data base

Recovery Priority	Task #	Description	Comment	Action	Who	Funding	Needs
3	3.3	Develop a non-scientific constituency and public information program directed toward enhancing recovery actions		1) Watchable wildlife partnership puts signs at most coastal river boat ramps	USFWS, FWC, ADCNR, MSDWFP, LDWF; Wildlife Federations—Florida, Alabama, Mississippi, and Louisiana	All Sponsors	
				2) Developed a gulf sturgeon video	USACOE, USFWS	USACOE and USFWS	
				3) Hillsborough River web site and signs for gulf-wide awareness	FWC, MML, HRGTF	FWC and Walt Disney Foundation	
				4) Gulf sturgeon intranet site on FMRI web site	FWC, St. Petersburg, Florida	FWC	
3	1.5.2	Assess the potential to develop genetic markers to differentiate wild and hatchery-produced gulf sturgeon	Funding of this task is dependent on task 1.4.3 decision	Awaiting UF report for recommendations	UF, IFAS, Gainesville, Florida	NMFS and FWC	Report recommendations
3	1.4.2	Identify physical, chemical and biological parameters necessary to maintain growth, health, and survival of fish reared under artificial conditions	Continuation of this effort is dependent on the outcome of 2.5.1	1) Develop culture techniques for gulf sturgeon	UF, IFAS, Gainesville,Florida; USFWS,Welaka NFH, Florida; Warm Springs NFH, Georgia	NOAA, SK, USFWS	1) Develop nutritionally balanced artificial diet
				2) Determine diet feeding periodicity	UF, IFAS, Gainesville, Florida	FWC, St. Petersburg, Florida	2) Report optimum water-quality conditions
				3) Determine environmental tolerances of sturgeon by oxygen demand	UF, IFAS, Gainesville, Florida	FWC, St. Petersburg, Florida	3) Evaluate carrying capacity of rearing facilities

3	1.4.3	Identify and test nongenetic internal and external markers or techniques to differentiate wild and hatchery-produced gulf sturgeon	Funding this task dependent on task 2.5.1 decision	See 1.5.2			1) Standardize internal and external marking procedures
3	4.4	Develop and implement a program to monitor numbers and habitat conditions of known populations in rivers and newly discovered, introduced, or expanding sturgeon populations		1) Gulf sturgeon population estimate—Suwannee River, Florida	CCC, Gainesville, Florida; USGS, BRD, Gainesville, Florida; IFAS, UF, Gainesville, Florida	Phipps Foundation; USGS; FWC	1) Surveys need for all remaining gulf sturgeon rivers in Florida, Alabama, Mississippi, and Louisiana
				2) Gulf sturgeon population estimate—Apalachicola River, Florida	USFWS, Panama City, Florida; NCSU, Raleigh, North Carolina	USFWS	2) Periodic evaluations using standard methods
				3) Gulf sturgeon population estimate—Choctawhatchee River, Florida	USFWS, Panama City, Florida; NCSU, Raleigh North Carolina	USFWS and USGS	
				4) Gulf sturgeon population estimate—Lower Pearl River, Louisiana and Mississippi	USACOE, Vicksburg, Mississippi	USACOE, LDWF, and MDWFP	
				5) Gulf sturgeon population estimate—Pascagoula River, Mississippi	USM, Hattiesburg, Mississippi; MMNS, Jackson, Mississippi	Sea Grant and NFWF	
3	5.1	Assess overall success of the recovery program and recommend action		1) Annual evaluation of recovery implementation progress	USFWS, Panama City, Florida		Continue annual evaluation of gulf sturgeon populations

APPENDIX H

Glossary of Common Acronyms in Text and Appendices

ACF—Apalachicola-Chattahoochee-Flint
ACT—Alabama-Coosa-Tallapoosa
ADCNR—Alabama Department of Conservation and Natural Resources
AFB—Air Force Base
AFS—American Fisheries Society
ASMFC—Atlantic States Marine Fisheries Commission
BMP—Best Management Practice
BOD—Biological Oxygen Demand
BRD—Biological Resources Division
CARL—Conservation and Recreational Lands
CCC—Caribbean Conservation Corps
CITES—Convention on International Trade in Endangered Species of Wild Fauna and Flora
DDT—Dichloro-diphenyl-trichloro-ethane
EPA—Environmental Protection Agency
FDACS—Florida Department of Agriculture and Consumer Services
FDEP—Florida Department of Environmental Protection
FDER—Florida Department of Environmental Regulation
FERC—Federal Energy Regulatory Council
FMRI—Florida Marine Research Institute
FNAI—Florida Natural Areas Inventory
FS—Florida Statute
FSPWG—Florida Sturgeon Production Working Group
FTC—Fisheries Training Center
FWC—Florida Fish and Wildlife Conservation Commission
GDNR—Georgia Department of Natural Resources
GIS—Geographical Information System
GSMFC—Gulf States Marine Fisheries Commission
HB—Hillsborough Bay
HRGTF—Hillsborough River Greenways Task Force
IFAS—Institute of Food and Agricultural Sciences (part of University of Florida)
JWLD—Jim Woodruff Lock and Dam
LDWF—Louisiana Department of Wildlife and Fisheries
MSDWFP—Mississippi Department of Wildlife, Fisheries, and Parks
MML—Mote Marine Laboratory
MMNS—Mississippi Museum of Natural Sciences
MSU—Mississippi State University
NCSU—North Carolina State University
NFH—National Fish Hatchery
NGO—Nongovernmental Organization
NMFS—National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NPDES—National Pollution Discharge Elimination System
NRCS—Natural Resources Conservation Service
NWFW—National Fish and Wildlife Federation
NWFWMD—Northwest Florida Water Management District
OFW—Outstanding Florida Waters
PCB—Polychlorinated biphenyls
SCDNR—South Carolina Department of Natural Resources
SK—Saltonstall Kennedy
SOR—Save Our Rivers
SOS—Save Our Suwannee
SWFWMD—Southwest Florida Water Management District
SWMD—Suwannee River Water Management District
TBNEP—Tampa Bay National Estuary Program
TED—Turtle Excluder Device
TNC—The Nature Conservancy
UF—University of Florida
USACOE—United States Army Corps of Engineers
USDOC—United States Department of Commerce
USEPA—United States Environmental Protection Agency
USFWS—United States Fish and Wildlife Service
USGS—United States Geological Service
USM—University of Southern Mississippi
WES—Waterways Experimental Station
WMD—Water Management District
WMLTF—Water Management Lands Trust Fund
YOY—Young-of-the-Year

Sampling Sturgeon in the Suwannee River, Florida, 1973

Florida Department of Natural Resources Marine Research Laboratory* personnel. *Top:* Wilmer Corbin and J. Alan Huff. *Bottom left and right:* Gerard Bruger.

Center: Gyotaku (fish printing) sturgeon by Laura Sloop-Hennings.

Photos by James Ryan, St. Petersburg Times, February 1973.

*Now Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute.